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Project title:

Creating knowLedge and skilLs in AddItive Manufacturing

CLLAIM

Metal AM Designer for PBF processes

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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

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

LEGAL NOTICE

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1. Preface

The present document consists in European Guideline for Metal AM Designer for PBF processes, 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 Designer for PBF Processes

3.1 Introduction to Metal AM Designer for PBF Processes

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	ED PBF	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 25: Post Processing	14	28
CU 59: Relevant principles of PBF Processes for Design	21	42
CU 60: Design Metal AM parts for PBF Processes	28	56
CU 61: Simulation Analysis	21	42
Subtotal (without optional CUs)		
CU 62: Simulation Execution	21	42
Total	**112**	**224**

* 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:

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

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3.2 Occupational Standard

Metal AM Designers for PBF Processes are the professionals with the specific knowledge, skills, autonomy and responsibility to design metal AM solutions for PBF Processes. His/her's main tasks are to:

- Design Metal AM solutions for PBF Processes ensuring and validating that parts can be made cost-effective and efficiently.
- Close PBF Processes design projects by verifying requirements for production with engineer as well as process requirements, ensuring liaison with other technical areas to sign of drawings.
- Contribute to projects in a teaming environment cooperation with AM Team.

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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 Metal AM Designer for PBF Processes admission are the following:

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

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3.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
ED PBF	ADVANCED	Advanced knowledge and critical understanding of the theory, principles and applicability of metal additive manufacturing design for DED processes.	Advanced problem-solving skills including critical evaluation and design thinking, allowing to choose the proper technical and economical solutions, when designing for DED metal additive manufacturing processes, in complex and unpredictable conditions.	Manage complex DED processes design projects, taking responsibility for decision-making in unpredictable DED processes design applications.

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3.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Designer for PBF Processes is listed below.

3.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview SUBJECT TITLE	RECCOMMENDED 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: – 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 25: Post Processing

CU 25: Post Processing	CONTACT HOURS
SUBJECT TITLE	
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

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3.5.3 Competence Unit 59: Relevant principles of PBF Processes for Design

CU59: Relevant principles of PBF Processes for Design SUBJECT TITLE	RECOMENDED CONTACT HOURS
PBF process capabilities	7
PBF process limitations	7
Design considerations	7
Total	21
WORKLOAD	**42**

Learning Outcomes – CU 59: Relevant principles of PBF Processes for Design	
KNOWLEDGE	Specialised, factual and theoretical of theory, principles and applicability of metal DED processes and related technologies: – Capabilities and limitations of PBF processes influence in design – Design considerations required for PBF parts design – Post processing influences in design
SKILLS	Associate the degrees of freedom of a PBF machine to the possibilities in terms of design Relate the capabilities and limitations of PBF to design considerations Determine dimensional constraints and geometric tolerances required for PBF parts design Provide solution-based approaches to redefine design problems (Design thinking) within PBF processes and parts

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3.5.4 Competence Unit 60: Design Metal AM parts for PBF Processes

CU 60: Design Metal AM parts for PBF Processes	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
Parts requirements	3
CAD Models & Software	12
Part optimisation	4
Designing parts	4
Design to cost	2
Data preparation for production	3
Total	28
WORKLOAD	**56**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	RECOMMENDED CONTACT HOURS	WORKLOAD
Design Metal AM parts for PBF Processes	6	Design Metal AM parts	Interpreting parts requirements	28	56
			Specifying lattice structures		
			Determining parts orientation (consider powder spreading and curl effect)		
			Redesigning parts		
			Assessing Costs in Design		
			Closing design project		

Learning Outcomes – CU 60: Design Metal AM parts for PBF Processes	
KNOWLEDGE	Advanced knowledge and critical understanding of: – Influence of Parts requirements in design; – Orientation and positioning of parts in the build chamber; – Design optimisation. .

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Learning Outcomes – CU 60: Design Metal AM parts for PBF Processes	
SKILLS	Verify and analyse requirements for production providing initial propositions and constraints Analyse relevant costs considering the requirements, materials, machine hour rate and manual preparations to ensure the most efficient design Test additively manufactured parts to assess the need for redesign (for example, when the part design is completed, and its performance needs to be tested. If it fails, some redesign may be needed.) Carry out reengineering design using metal AM to design parts previously produced by conventional processes/methods Ensure liaison with other technical areas (process, production, etc.) Sign off (ESO) drawings (STL/AMF files included)

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3.5.5 Competence Unit 61: Simulation Analysis

CU 61: Simulation Analysis	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
Evaluation of Topology Optimization (TO)	3
Mechanical Analysis	3
Fatigue	2
Chemical	3
Thermal Analysis	2
Build Evaluation	2
Documentation	2
Case studies	4
Total	21
WORKLOAD	**42**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	RECOMMENDED CONTACT HOURS	WORKLOAD
Simulation Analysis	6	Analyse simulation results	Evaluating Topology Optimization (TO) Interpreting finite element (FE) simulation results Documenting technical conclusions deriving from simulation results	21	42

Learning Outcomes – CU 61: Simulation Analysis	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Topology Optimization – Stress and Strain Analysis – Phase transformations
SKILLS	Verify compliance between part requirements and simulation results Run topology optimization considering part requirements interpretation in terms of in-service conditions Define part design improvements based on simulation results Elaborate simulation analysis reports proposing production strategies

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3.5.6 Competence Unit 62: Simulation Execution

CU 62: Simulation Execution	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
Pre-Processing	7
Processing	7
Validation	7
Total	21
WORKLOAD	**42**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	RECOMMENDED CONTACT HOURS	WORKLOAD
Simulation Execution	6	Simulate and predict impressions	Execute/perform Topology Optimization	21	42
			Creating finite simulation models (FEM)		
			Debugging modelling optimization		

Learning Outcomes – CU 62: Simulation Analysis	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Validation and Calibration strategies – Application of the relevant Material properties, Boundary conditions and mesh characteristics
SKILLS	Choose appropriate CAD file extension to export geometry to the FEA software workspace Judge the type of Simulation Analysis (e.g. Structural, CFD, etc.) according to the problem characteristics Assign physical properties (e.g. material, Boundary conditions, etc) to the geometry to reproduce the in- service solicitations Select proper element type, size, solver and time step to generate a computationally time effective mesh Appraise the quality of the model by comparing physical aspects between the simulation and reality Perform an analysis to assess the converging characteristics of the model Elaborate simulation reports specifying part geometry, boundary conditions, mesh characteristics, material model

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