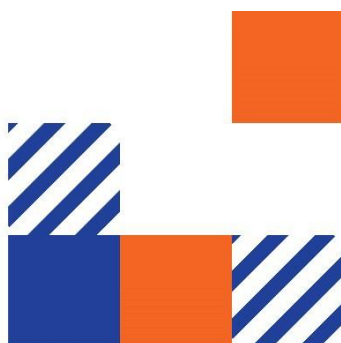




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Creating knowLedge and skillS in Additive Manufacturing



CLLAIM

Metal AM Operator DED-arc

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

/

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

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1. Preface

The present document consists in European Guideline for Metal AM Operator DED-arc, developed in the framework of the European project “Creating KnowLedge and SkillS in Addlitive 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 Operator DED - Arc

3.1 Introduction to Metal AM Operator DED - Arc

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-Arc | |
|--|----------------------------|--------------------|
| | Recommended Contact Hours* | Expected Workload* |
| CU 00: Additive manufacturing Process Overview | 7 | 14 |
| CU 01: DED-Arc Process | 14 | 28 |
| CU 02: Quality Assurance (QA) in DED-Arc | 7 | 14 |
| CU 03: Health, Safety and Environment (HSE) in DED-Arc | 7 | 14 |
| CU 04: Fit and set-up of DED-Arc systems | 21 | 42 |
| CU 05: Manufacturing of DED-Arc parts | 7 | 14 |
| CU 06: Post processing of DED-Arc parts | 7 | 14 |
| CU 07: Maintenance of DED-Arc systems | 14 | 28 |
| 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.

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

3.2 Occupational Standard

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

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

He/She will be able to:

- Verify arc related parameters and positioning in DED-Arc machines for AM;
- Self-manage the handling of feedstock (approval, storage, contamination, traceability);
- Develop solutions on basic and specific problems related with DED-Arc machines and processes for AM.

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

3.4 Qualification Outcome Descriptors

| QUALIFICATION | EFW LEVEL | KNOWLEDGE | SKILLS | AUTONOMY AND RESPONSIBILITY |
|---------------|-------------|--|--|--|
| EO DED–Arc | INDEPENDENT | Factual and broad concepts in the field of DED–Arc 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–Arc manufacturing problems | Self-manage of professional activities and simple standard applications of of DED–Arc manufacturing in predictable contexts but subject to change. |

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 | RECOMMENDED 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: <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 | <p>Factual and broad of:</p> <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 | <p>Describe the DED–Arc 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–Arc parameters and the influence of their adjustment on the as built part (e.g. deformation)</p> <p>Recognise the characteristics of the DED–Arc 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–Arc</p> |

3.5.3 Competence Unit 02: Quality Assurance (QA) in DED-Arc

| CU 02: Quality Assurance in DED-Arc | RECOMENDED CONTACT HOURS |
|-------------------------------------|--------------------------|
| SUBJECT TITLE | |
| General QA principles | 3 |
| AM Machine QA | 2 |
| AM Parts QA | 2 |
| Visual Inspection Overview | 4 |
| Total | 11 |
| WORKLOAD | 22 |

| Learning Outcomes – CU 02: Quality Assurance in DED-Arc | |
|--|---|
| KNOWLEDGE | <p>Factual and broad knowledge of:</p> <ul style="list-style-type: none"> – Quality Assurance in DED-Arc – Standard operating procedures – Overall overview of process flow from costumer purchase order to delivery of finished part – Receiving inspection of feedstock and build platform – Receiving inspection of non-consumable electrodes and constricting nozzles in DED-Arc – Material staging and preparation – Visual Inspection of DED-Arc |
| SKILLS | <p>Recognise the broader use of QA within engineering</p> <p>Recognise the scope of the DED-Arc operator qualification within the AM industry</p> <p>Support the qualification and requalification procedures of DED-Arc equipment</p> <p>Identify the main procedures, equipment and their role</p> <p>Prepare test reports based on the requirements specified by the manufacturer</p> <p>Compare geometry and dimensions specified in the technical drawings with the as built parts</p> <p>Use simple measurement devices and techniques to carry out a basic visual inspection of the as built part</p> <p>Identify problems in the as build parts distinguishing between imperfections and defects</p> <p>Report defects suggesting either their removal with post processing operations or part disposal</p> |

3.5.4 Competence Unit 03: Health, Safety and Environment (HSE) in DED-Arc

| | |
|--------------------------------|---------------|
| CU03: HSE in DED-Arc | CONTACT HOURS |
| SUBJECT TITLE | |
| Health, Safety and Environment | 7 |
| Total | 7 |
| WORKLOAD | 14 |

| Learning Outcomes – CU03: Health, Safety and Environment (HSE) in DED-Arc | |
|---|--|
| KNOWLEDGE | Factual and broad of: <ul style="list-style-type: none"> – Health, Safety and Environment related to DED-Arc |
| SKILLS | Identify the main hazards and safety measures associated with DED-Arc systems Recall existing legislation and requirements on HSE procedures related to DED-Arc |

3.5.5 Competence Unit 04: Fit and set-up of DED-Arc systems

| | |
|--|---------------|
| CU04: Fit and set-up of DED-Arc systems | CONTACT HOURS |
| SUBJECT TITLE | |
| DED-Arc processes and systems requirements | 5 |
| Loading of files and Work Documentation | 4 |
| Operational Parameters | 7 |
| Materials handling and how it relates to the process | 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-Arc systems | 4 Independent | Fit and set-up the DED-Arc system | Verifying the DED-Arc system set-up the procedure determined by the machine manufacturer and required operational conditions (e.g. electric arc power supply, gas supply, cooling system, torch) | 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) | | |

| | | | | | |
|--|--|--|---|--|--|
| | | | Verifying parameter specifications (e.g. voltage, current, wire feed speed, travel speed, contact tip to work distance, positioning of the substrate) | | |
| | | | Following HSE procedures for the fit and set-up of the DED-Arc system | | |
| | | | Following and completing work documentation created by the DED-Arc Engineer | | |

| Learning Outcomes – CU04: Fit and set-up of DED-Arc systems | |
|---|---|
| KNOWLEDGE | <p>Factual and broad of:</p> <ul style="list-style-type: none"> – Variables of DED-Arc and related operational conditions parameters – DED-Arc Equipment Requirements – Materials used for DED-Arc – Type of files and Work documentation – HSE procedures under DED-Arc |
| SKILLS | <p>Prepare the system for operation, according to the Additive Manufacturing Procedure Specification</p> <p>Verify if the machine is working in accordance with the job specification, in terms of process parameters</p> <p>Prepare the feedstock, build platform and the machine in accordance to the used material</p> <p>Verify if the DED-Arc machine complies with the machine manufacturer and/or internal specifications</p> <p>Load files to DED-Arc machine</p> <p>Comply with HSE procedures associated to a DED-Arc machines</p> <p>Interpret technical information related to the DED-Arc processes and machines</p> |

3.5.6 Competence Unit 05: Manufacturing of DED-Arc parts

| | |
|--|---------------|
| CU05: Manufacturing of DED-Arc parts | CONTACT HOURS |
| SUBJECT TITLE | |
| Machine functionalities and monitoring systems | 5 |
| Documentation | 1 |
| HSE procedures | 1 |
| Total | 7 |
| WORKLOAD | 14 |

| CU | EQF/ EWF LEVEL | JOB FUNCTIONS | JOB REQUIRED ACTIVITIES | CONTACT HOURS | WORKLOAD |
|--------------------------------|----------------|--------------------------------|--|---------------|----------|
| Manufacturing of DED-Arc parts | 4 Independent | Manufacturing of DED-Arc parts | Performing a dry run and machine calibration at the beginning of the production run | 7 | 14 |
| | | | Ensuring that the layers are manufactured according to the quality requirements (i.e. first layers and periodically) | | |
| | | | Monitoring the machine and the manufacturing process | | |
| | | | Following HSE procedures when manufacturing DED-Arc parts | | |
| | | | Following and completing work documentation | | |

| | | | | | |
|--|--|--|--|--|--|
| | | | according to the quality requirements | | |
| | | | Reporting issues and implementing corrective or preventive actions based on parts' requirements feedback from the Engineer | | |

| Learning Outcomes – CU05: Manufacturing of DED-Arc parts | |
|--|---|
| KNOWLEDGE | Factual and broad of: <ul style="list-style-type: none"> - Manufacturing of DED–Arc parts - DED–Arc machine functionalities and monitoring systems |
| SKILLS | Set-up the clamping system for the build platform characteristics according to the clamping plan (e.g. shape, thickness, material) Perform manufacturing of parts according to the build instruction applying HSE procedures Identify the main reasons for failure during the manufacturing process Interpret technical documentation related to the requirements of the as built parts Prepare reports on the manufacturing process, including identified issues |

3.5.7 Competence Unit 06: Post processing of DED-Arc parts

| | |
|--|---------------|
| CU06: Post processing of DED-Arc parts | CONTACT HOURS |
| SUBJECT TITLE | |
| Post build cycle operations including manual tools and methods | 3 |
| HSE procedures | 4 |
| Total | 7 |
| WORKLOAD | 14 |

| CU | EQF/ EWF LEVEL | JOB FUNCTIONS | JOB REQUIRED ACTIVITIES | CONTACT HOURS | WORKLOAD |
|-------------------------------------|----------------|---|--|---------------|----------|
| Post processing of DED-Arc parts | 4 Independent | Prepare DED-Arc parts for post processing | Providing information from monitoring data about critical areas for extended testing | 7 | 14 |
| | | | Unclamping the part | | |
| | | | Performing basic verification of as built parts | | |
| | | | Applying manual operations to parts (cleaning, subtractive & other post processing) | | |
| | | | Handing parts for post processing operations | | |
| Following applicable HSE procedures | | | | | |

| Learning Outcomes – CU06: Post processing of DED-Arc parts | |
|--|---|
| KNOWLEDGE | Factual and broad of: <ul style="list-style-type: none"> – Manual tools and methods for post-processing operations |

| Learning Outcomes – CU06: Post processing of DED-Arc parts | |
|---|--|
| SKILLS | Remove the as built parts from the machine applying the necessary HSE procedures Carry out simple manual preparation of the as built part for different post-processing methods |

3.5.8 Competence Unit 07: Maintenance of DED-Arc systems

| | |
|--------------------------------------|---------------|
| CU07: Maintenance of DED-Arc systems | CONTACT HOURS |
| SUBJECT TITLE | |
| Periodic maintenance aspects | 5 |
| Mechanical parts maintenance | 5 |
| Gas supply system maintenance | 2 |
| Auxiliary elements maintenance | 2 |
| Total | 14 |
| WORKLOAD | 28 |

| CU | EQF/ EWF LEVEL | JOB FUNCTIONS | JOB REQUIRED ACTIVITIES | CONTACT HOURS | WORKLOAD |
|--------------------------------|----------------|-------------------------------------|--|---------------|----------|
| Maintenance of DED-Arc systems | 4 Independent | Maintain and repair DED-Arc systems | Implementing equipment manufacturer's maintenance routines | 14 | 28 |
| | | | Cleaning and replacing components (e.g. feedstock spool, electrode tip, nozzle, liner, coolant, gas supply components) | | |
| | | | Reporting problems to the Engineer | | |
| | | | Following applicable HSE procedures | | |

| Learning Outcomes – CU 07: Maintenance of DED-Arc systems | |
|--|---|
| KNOWLEDGE | <p>Factual and broad of:</p> <ul style="list-style-type: none"> – Maintenance aspects associated with DED-Arc systems |
| SKILLS | <p>Assess the need to perform maintenance operations in DED-Arc system</p> <p>Perform maintenance operations in a DED-Arc system</p> <p>Identify the consumables for the different machine parts</p> <p>Report the need to execute specific maintenance</p> <p>Support other technicians during system maintenance</p> <p>Verify monitoring and calibration status (e.g. CNC/robot encoders)</p> <p>Verify the level of wear of a mechanical component (e.g. nozzles, rollers, contact tips)</p> <p>Replace, clean and repair mechanical components according to manufacturer instructions</p> <p>Change filters in the shielding gas system</p> <p>Verify the welding gas and fume extraction system flows</p> <p>Verify the condition and make use of the personal protective equipment</p> |

