Deliverable D7.15

Training the Trainers
Delft University of Technology
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1. Introduction

The "training-of-trainers" outreach activity intends to define the content outline of courses for WAAM specialists. The expertise gathered in the Grade2XL project could provide additional course material to existing initiatives for qualification of professionals to ensure that they are equipped with the right skills to implement WAAM at industrial level.

The European Welding Federation is involved in an International Additive Manufacturing Qualification System (IAMQS) that has the scope to develop training guidelines for a wide variety of AM processes and materials [1]. Collaborating partners include among others consortia of (former) European funded projects like SAM [2], cllaim [3], Lasimm [4], admire [5], openhybrid [6] and encompass-am [7].
The system has a modular structure and currently a dozen 'Qualifications in Additive Manufacturing' are offered. The system has an internationally accepted approach to harmonise training, qualification and certification, involving training institutes, national certification bodies, companies, trainers and trainees. The system should assure that any certified person has a similar set of expertise and skills. It is stated that currently two main hurdles have to overcome in AM, being a) the absence of comprehensive and all-encompassing curricula for education, and b) the availability of skilled employees. Figure 1 presents an overview of a roadmap for strategic objectives for AM education [2], identifying gaps.

Figure 1: Roadmap strategic objectives for AM.

The courses designed in the IAMQS, detailed in the catalogue [1] have a modular structure and have a cumulative character. The modules are differentiated to designer, operator and process engineer level. From a process point of view the modules focus on Powder bed Fusion, Directed Energy Deposition - Laser beam, Directed Energy Deposition - Arc. Finally, modules for International Coordinator and International Supervisor are available.

The focus of Grade2XL is on Wire and Arc Additive Manufacturing. In the IAMQS catalogue 2 modules are addressing this technology: Operator Directed Energy Deposition Arc Personnel (I MAM O DED-Arc) and Process Engineer Directed Energy Deposition Arc Personnel (I MAM PE DED-Arc).

The target group of the Operator qualification has no experience, knowledge, skills and competences in the field of DED-Arc Additive Manufacturing or people who would like to up-grade their knowledge. The course with a recommended duration of 80 hrs, consists of the following content:

- Additive Manufacturing Processes Overview (3.5)
- DED-Arc Process (14)
- Quality Assurance in DED-Arc (7)
- Health, Safety and Environment in DED-Arc (7)
- Fit and set-up of DED-Arc systems (14)
- Manufacturing of DED-Arc parts (7)
- Post processing of DED-Arc parts (7)
- Maintenance of DED-Arc systems (14)

The target group of the Process Engineer Directed Energy Deposition Arc Personnel is intended for engineers willing to specialize and pursue a career in DED-Arc. The tasks involved also require validation of design, implementation pre- and post-process operations, assurance of part conformity etc. The course recommended study duration is 143.5 hrs + two selected materials.

- Additive Manufacturing Processes Overview (3.5)
- DED-Arc Process (42)
- Post processing (14)
- Materials (selection of two materials)
    - AM with Steel feedstock (excluding Stainless Steel) (21)
    - AM with Stainless Steel feedstock (14)
    - AM with Aluminium feedstock (7)
    - AM with Nickel feedstock (7)
    - AM with Titanium feedstock (14)
    - AM with Tungsten feedstock (3.5)
- Biomedical metallic materials (7)
- Production of DED-Arc parts (28)
- Conformity of DED-Arc parts (42)
- Conformity of facilities featuring DED-Arc (14)

For the designer for DED-Processes, a course with the following content is described 87.5 hrs.

- Additive Manufacturing Process Overview (3.5)
- Post Processing (14)
- Relevant principles of DED Processes for Design (14)
- Design Metal AM parts for DED Processes (35)
- Simulation Analysis (21)

It can be seen that for these three qualifications a number of similar course units are provided. Furthermore it can be expected that the operator and process engineer have a certain affinity with welding. The course unit provide the general knowledge/skills on the WAAM process. Furthermore, some basic information on materials is presented. This in particular also a good starting point for design for AM.

The entire Grade2Xl program may contribute to providing more detailed information on AM-part design, process innovation including in-line monitoring of the process, materials selection, pre- and post-processing, certification of printed parts, environmental impact.

Design based on topology optimisation is a standardised methodology. The outcome of the simulations should of coarse be analysed for printability. The course unit could be expanded towards multi-material and/or multi-process parameter design. (Task 1.6 Grade2XL)

Process innovation could involve multi-wire systems for increasing deposition rates or compositionally grading components, hybrid technologies (additive + subtractive). In-line monitoring of the process detect anomalies in printing parameters to be related to defect formation. This could eventually be extended to process loops for defect repair.

The personnel should be aware of the characteristics of the materials selected in the design process. For multi-material designs the compatibility of the materials should be addressed. Furthermore, wires are being specifically developed for additive manufacturing. The strategy of the wire development could be included in a course unit, why are WAAM wires different from welding wires.
Pre- and/or post heat treatments might be considered for residual stress relaxation, tempering, grain refinement, but this in principle similar to welding operations.

Attention should be paid to the certification of processes and products in AM. Standards are being in development, but it is required that this topic is addressed for companies intending to implement WAAM.

Last but not least, life cycle assessment is a topic that gains more and more importance for WAAM. Sustainability and environmental impact should be carefully considered for material and process selection.

These topics will be discussed for future implementation in AM course in the final deliverable.

2. References:

1. Catalogue Additive Manufacturing Qualifications Version 2 (2022), www.ewf.be/qualification/iamqs
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