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Simulation Welding using XR technology

Education and Training in Welding

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Foreword

The series "Digital Manufacturing" aims to present the technologies involved in modern manufacturing, controlled by specialized computer systems. Specific elements of manufacturing systems will be addressed, such as joint and micro-joint technologies, referral technologies for automated systems, mechanical processing technologies and others. The approach is a little descriptive, not wishing to develop manuals for training operators.

This book addresses to engineers and researchers who are involved in research and development activities related to welding processes using digital tools like welding simulators in order to be able to create new products.

The topics discussed are related to welding and digital education in welding using XR technologies. The book ends with a chapter dedicated to real life welding study cases that can be simulated on welding simulator.

The results presented in this book represents the outputs of European project funded by:

Erasmus+ Programme grant no. 2018-1-RO01-KA202-049218, with title Innovative digital tool for training in the field of welding, acronym DIGIWELD.

1. INTRODUCTION

The goal of this module is to present the updates related to specific curricula for trainees based on European Guidelines, incorporating a welding simulator as a viable and innovative tool for education and training of future welders, which constitutes a major step forward for new digitised teaching methods. The reason of updating welding curricula is the enhancement of the attractiveness of the qualification among youngsters, among experienced welding professionals who search for an upskilling in welding and the acquisition of ICT competences.

1.1 General aspects regarding European Welder Guideline

The European Welder Guideline was developed by the European Federation for Welding, Joining and Cutting (EWF) and reflects the results from discussions on the basics of welding technology. It is divided in two parts:

- Part I (EWF-IAB-089r45-14) refers to the standard scheme for educating welders;
- Part II is optional and details test objects and Welding Procedure Specification (WPS) to be used for test object examination.

The EW Guideline (course) provides methods for both theoretical and practical education and training at three levels: Fillet, Plate and Tube Welders. The update of the EW Guideline/curriculum has been identified as an answer to the need to encompass new technologies and teaching methods for trainers/teachers and improve the education and training process by focusing on trainees' needs, providing them with the best learning materials, complying with the latest requirements.
By using digital technologies in training, trainees will acquire welding skills and digital competences in a practical way. The introduction of open and innovative learning digital tools in the EW Guideline will allow the reduction of time and cost in training. It will also make training closer to native digital skills of the new generation of apprentices. The proposal to update the EW curriculum consists of ensuring a harmonised use of a welding simulator in the practical training, defining the criteria for its use in terms of assessing trainees' performance before moving to a real- life welding machines. This update also suggests the introduction of a new Competence Unit (CU) focusing on Computer and Simulator in order to allow trainees to acquire basic skills and knowledges in the use of digital tools and, therefore, prepare them not only for the use of the welding simulator, but also for the use of the Learning Management System (LMS), a digital platform dedicated to training, practice and assessment of trainees' skills and knowledges.

1.2 Analysis of needs requirements

The analysis of needs requirements related to introduction new chapter regarding computer and simulation in training curricula requires surveys among welding specialists and teachers/trainers from higher education, VET schools and training centers.

1.2.1 Survey on welding specialists

The survey among welding specialist covered three important sections as follows:

- Access conditions for apprentices: according to most part of the answers provided, basic knowledge and skills in digital tools should be considered as access condition to european welder course
- Topic related to computer and simulation: majority of answers stated that is a need for the creation of new competence unit in computer and simulation, which is important for welding apprentices to acquire needed basic skills and knowledge for using digital tools (such as welding simulators) and learning management systems.

The competences, skills attitudes that will be transmitted to future welders should be:

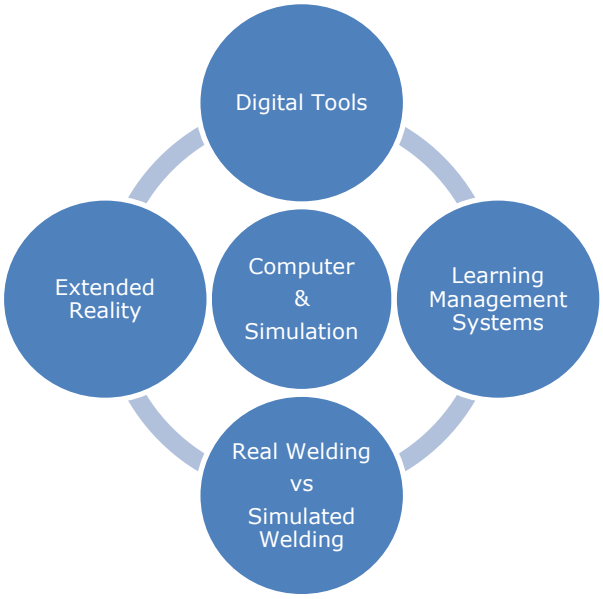

Fig. 1.1 Knowledges, skills and attitudes for computer and simulation unit

- Practical training: for this section, a comparison between the countries from Europe was carried out, focusing on the respective National Qualifications Framework (NQF) and their connection to the EWF-IIW Guidelines. Asurvey under Erasmus+ Project

DIGIWELD was carried out covering Portugal, Spain, Romania and Italy:

- Portugal: NQF level 2
- Spain: NQF level 2
- Romania: NQF level 3
- Italy: no indication on the NQF level for this Qualification once this country is still working towards the alignment of the national qualifications with the European Qualifications Framework (EQF).

In the Portuguese and in the Spanish VET systems, Welder Qualification is already included in the national VET qualifications catalogues. As for NQFs' connection to the EWF-IIW Guideline, national qualifications' catalogues may confer a different qualification level from the one conferred by the EWF system. For example, the Welder Qualification is a level 2 qualification in the Portuguese National Qualifications Catalogue, while in the EWF system it can range from a level 2 to a level 4 qualification. In Romania, there is no alignment between the Welder Qualification NQF level and the EWF system and in Spain the Tube Welder qualification (part of the Welder Qualification) does not exist in the Spanish National Qualifications Catalogue.
All countries organise the Welder Qualification by process, except for Italy which organises it only by joint type. In Romania, besides process, the Qualification is also organised by material and joint type, as showed in the table below:

Table 1.2 Organization of welder qualification by countries

EWF (PT)	ATS (ES)	ASR (RO)	CESOL (ES)	CNT (RO)	IIS (IT)
By process	By process	By process By material By joint type	By process	By process By material By joint type	By joint type

The number of hours required in practical Welding training sections considering welding process, material(s) joint types and position(s) varies from country to country due to their respective national legislation. All EW theoretical and practical modules will be considered in the welding training simulator that will be used in EW practical training, provided that the welding positions taught are available in the simulator. However, it must be taken into account that not all positions will be carried out due to their specificities (e.g. full penetration in butt joints). Nevertheless, simulator training can represent several repetitions since no special preparation of the materials and position in a jig is necessary.
In the following table, it is possible to verify that, on average, training in welding have a total duration of 2000 hours and can be divided between regular and professional courses:

Table 1.2 Description of practical welding training sections

Country (Participant)	Description of practical welding
Portugal (EWF)	Technological Training in Welding in Portugal is based on: A. **Pre-defined Short-Term Training Units** comprised in a total of 800 hours, which include: i. MAG = 250 hours ii. TIG = 100 hours iii. Work-based learning = 120 hours B. **Set of Short-Term Training Units**, comprised in a total of 1000 hours, which include: i. MAG = 275 hours ii. TIG = 450 hours iii. MIG = 250 hours This training has two education modalities (Adult Education and Training and Modular Training) and is provided to VET schools in a Training Referential managed by the National Qualification Agency Authority (ANQEP), in accordance with EWF/IIW Guidelines.
Spain (ATS/ CESOL)	In Spain there are two types of professional training in welding: one regulated within the traditional educational system (FP) and another within the professional training for employment (FPE). Each one has its own legal regulations at national and regional level. **Welding and Boiler Technician (FP) – CINE 3 – 2000 h** of which **530** are practical welding training: - Professional module: Welding in a natural atmosphere. 290 h - Professional module: Welding in a protected atmosphere. 240 h **Professional Qualification in Welding (FPE) – 1280 h** of which **600** are practical welding training: - Welding and thermal projection by oxygas (140 hours) - Arc welding under protective gas with consumable electrode (130 hours) - Arc welding under protective gas with non-consumable electrode (130 hours) - Welding with electric arc with coated electrodes (200 hours)
Romania (ASR/CNT)	According to Romanian national laws, there can be 2 situations: 1. Practical training for formation of welders using two paths: through National Education System and through Welder National Qualification: a. National Education System: 930 hours divided by: i. MIG = 250 hours ii. MAG = 250 hours iii. TIG = 250 hours iv. MMA = 180 hours b. Welder National Qualification: 480 hours 2. Practical training for specialization in specific domain of welding: 80 hours
Italy (IIS)	No specific requirement is given in the national legislation (as it may be applicable, it only refers to ISO 9606)

Participants were asked what the percentage of time used in the welding simulator for exercises should be, considering the average time recommended by the EW Guideline for the exercises in each module of the course. Participants were unanimous to recommend that training/exercises in the simulator should constitute 50 to 60 percent of the practical training hours in each module, and that there is no need to create a new module on the simulator itself. It means that, for example, 60% of the time recommended in European Welding Guideline for exercises on the Competence Unite/Module dedicated to TIG Welding should be carried out in the welding simulator. the welding simulator exercises should be implemented before the use of real-life welding machines, once:

- "Training before welding using a welding machine will allow students to learn their positioning relative to the piece to weld depending of the welding position. Will also allow the learning of the torch, adjust the needed welding speed, and other operational variables related to the welders' job. So, the example of the apprentice to repeat all the exercises at least 2 times (or when the Trainer considers the student is ready, before moving to real life welding exercises) can be the way to go."
- "The apprentice should make all the exercise at least once."
- "The apprentice should gain successful results on the simulator before moving to the use of real welding machines".

There was also an opinion that defended a flexible process in which the theoretical training carried out both in Learning Management System and in the classroom could alternate with practice in the simulator and real welding workshop, to which apprentices only go on if they have passed the practical exercises in the simulator and the teacher determines that they are prepared to do it in the workshop.
Practical training in simulator will have all these opinions in consideration, but mainly will be used before the real-life welding, to which trainees will only move when achieving a given score percentage, with or without aid from the simulator. According to ATS, it will allow to configure the level of help the exercises will provide. Depending on the EW module, there may be total, some or no aid.
Currently in the EW Guideline, trainees are evaluated by trainers in all exercises they carry out, and these evaluations can be considered as intermediate exams. Most partners agree that these intermediate exams should not be carried out using the welding simulator. However, if so, the level of difficulty to be considered for these exams should be "hard", with no aid from the simulator.

1.2.1 Survey on teachers/trainers and other specialists

Result show that more than 40% of participants consider the use of digital tools to be very relevant in welding training, even though 61% of them do not use them (but are considering implementing them in their training, including welding simulators). Online training platforms and welding

simulators are viewed as the most relevant digital tools to be used in training, which causes trainees to need a certain level of know-how on digital tools to access the training course, according to participants. When asked what the main advantages of using simulators are in the welding training, based on response options provided to participants, the answers were as showed in the graphic below:

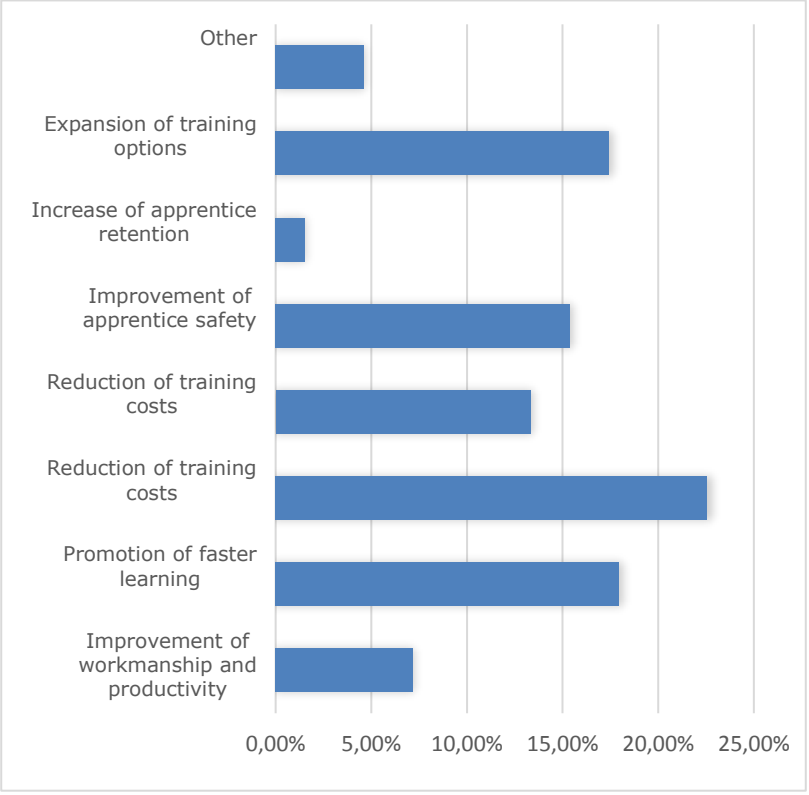

Fig. 1.2 Advantages in using welding simulators on welding training

Reduction of training costs, promotion of faster learning, expansion of training options and improvement of apprentice safety are the most chosen options by participants.

Regarding the replacement of real-life welding training by the usage of welding simulators in welding training, 35% of participants indicated to agree with a replacement between 30 to 50% of the training time and 30% agrees with that replacement between 10 and 30% percent of the time.

From a total of 61 answers, 43 were that welding simulators can be used for intermediate evaluation to allow trainees to move from simulation training to real life welding. For participants, the level of difficulty of this intermediate evaluation should be medium, with some aid from software.

In case the trainee would not adapt to the welding simulator, 90% of

participants agree that the welding instructor/trainer can override the virtual evaluation, allowing the apprentice to move to real-life welding.
The main results achieved concluded that:

- If using welding simulator for the practical training, the trainees must have basic knowledge and skills in digital tools.
- The new theoretical Competence Unit to be created will be entitled A.10/B.10/C.5 – Introduction to Computer and Simulation, will have 4 contact hours and will be developed to introduce trainees to the digital tools used by the training provider (Approved Training Body, or ATB).
- The practical hours of training were assessed, and the proposal considered is to split the minimum recommended hours to a minimal of 40% in the real welding equipment. This division might need to be evaluated individually by exercise, as there may be some cases, due to difficulty inherited to the process and position, where more time may be needed in the real welding equipment.
- During the training on the welding simulator the apprentice must go through all the exercises and should attain at least 60% in each exercise, without any aid from the simulator before moving to practical training in the real welding equipment and environment. The trainer will assess the welding capabilities and has the final decision if the trainer is moving towards training with the real welding equipment.

1.3 Computer and simulation in EW Guideline

The following proposals for the update of EW Guideline are based on the results from the Internal and External Surveys presented in section 3 of the present report, and include: the Access conditions to the EW course; the introduction of a new CU entitled "Computer & Simulation" and the procedures for the use of welding simulators on practical training of trainees. In EW Guideline, more specifically in its Section 2 – Access to the Course, a description of the minimal requirements to access to EW course is provided. There are two routes to access to the course: a Standard Route and an Alternative one.
For the Standard Route Qualification Access, which indicates that "Applicants must possess sufficient knowledge of, or education in, metalworking to follow the course", DIGIWELD project proposes to add a sentence to this requirement, to be taken in to account by ATBs that use welding simulators for trainees' practical training: If a welding simulator is used for the practical training, applicants must have basic knowledge and skills in digital tools. This new theoretical CU will address the knowledge gaps that trainees may present regarding the usage of new training tools and enable trainees to use them on practical exercises and move forward with training. It will also focus on simulation systems in terms of sensors, interfaces, physical parts, augmented reality, etc.
This new CU (or Module) is set as optional and will be applied to training