ARC+®: Teach Welders in a Virtual Environment

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Abstract

123 Certification Inc., a Montreal based company, has developed an innovative hands-on welding simulator solution to help build the welding workforce in the most simple way. The solution lies in virtual reality technology, which has been fully tested since the early 90's. President and founder of 123 Certification Inc., Mr. Claude Choquet Ing. Msc. IWE, acts as a bridge between the welding and the programming world. Working in these fields for more than 20 years, he has filed 12 patents world-wide for a gesture control platform with leading edge hardware related to simulation. In the summer of 2006, Mr Choquet was proud to be invited to the annual IIW International Welding Congress in Quebec City to launch the ARC+ welding simulator. A 100% virtual reality system and web based training center was developed to simulate multi-process, multi-material, multi-position, and multi-pass welding. The simulator is intended to train welding students and apprentices in schools or industries. The welding simulator is composed of a real welding electrode holder (SMAW-GTAW) and gun (GMAW-FCAW), a head-mounted display (HMD), a 6 degrees of freedom tracking system for interaction between the user's hands and head, as well as external audio speakers. Both guns and HMD are interacting online and simultaneously. The welding simulation is based on the law of physics and empirical results from detailed analysis of a series of welding tests based on industrial applications tested over the last 20 years.[1]

The simulation runs in real-time, using a local logic network to determine the quality and shape of the created weld. These results are based on the orientation, distance, and speed of the welding torch and depth of penetration. The welding process and resulting weld bead are displayed in a virtual environment with screenplay interactive training modules. For review, weld quality and recorded process values can be displayed and diagnosed after welding. To help in the learning process, a learning curve for each student and each Virtual Welding Class® can be plotted, for an instructor's review or a required third party evaluation.

Introduction

By way of introduction, here is a quote from the senior editor of the US-based magazine The Fabricator:

"A recent study led to an odd conclusion: Playing video games may produce better surgeons."

Really, it's true, at least according to researchers at the Banner Health Center in Phoenix. They had surgical residents play games on the Nintendo® Wii™ console before simulated surgeries. Games such as Marble Mania require precise hand movements of the Wii's wireless wand, movements that seem to prep these residents for the hand movements surgery requires.

In a certain light, welding resembles surgery, with careful hands "stitching up" metal instead of skin..." [2]-[3].

Work accomplished

A welder's helmet and welding gun have been instrumented for the welding simulator ARC+. The electronic sensors and the head mounted device are installed in order to provide visibility during welding. It tracks the hand motions and process while the 3D glasses inside the Welder's Helmet provide high 3D graphics (Fig. 1).

Figure 1: Real Welder Helmet with motion tracking technology Source: 123Certification Inc.

Figure 2: A virtual reality simulation of gas metal arc welding a fillet weld (GMAW). Source: 123 Certification

The solution is based on 100% virtual reality welding simulation without arc and metal work piece. High resolution images can be seen by the student on 3D glasses, and projected on a screen for classroom observation or replays. Under supervision, the welder can learn how to maintain a weld pool, arc length and consistent welding bead.. He can also learn how to cope with the 3 arc metal transfer mode (short-circuit, globular and arc spray), sparks and virtual fumes and volatiles. The database link to the simulator and the welder's motion activities reproduces the same results obtained in a welding booth.

As this technology evolves, increasing attention will be paid to the development of fine motor skills. For example, the simulator is able to track head and hand motions during a weld, helping the student determine the optimal angle of view while laying down a weld bead. Next research activities will be on image rendering of grain microstructure recrystallization after welding in the H.A.Z responsible for quality such as metallurgy based weld defects. (Fig. 2).

The ARC+ simulator is capable of all manual and semi-automatic welding processes (Fig. 3). At the time of this article, more than 50 welding data sheets and 1500 exercises had been implemented. An approximate 900 hours of exercises are available for perfecting fine motor skills. The possibilities of exercises are limitless. All welding data sheets with different processes, materials, welding positions, assembly preparations, multi-pass, weaving or linear are available.

This presentation will focus on light alloys requiring GTAW (TIG Welding) such as components submitted to heat from airplane reactors. (Fig. 4).

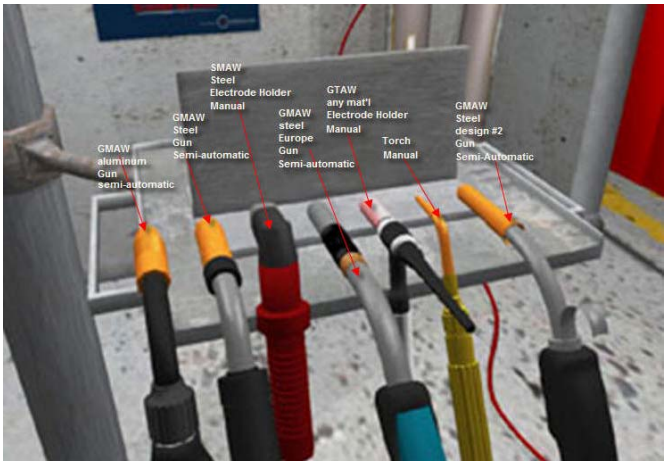

Figure 3: ARC+ simulates all these manual and semi-automatic welding processes Source: 123Certification Inc.

Figure 4: ARC+ welding simulator in action with the GTAW (TIG Welding) for a welder training.Source: 123Certification

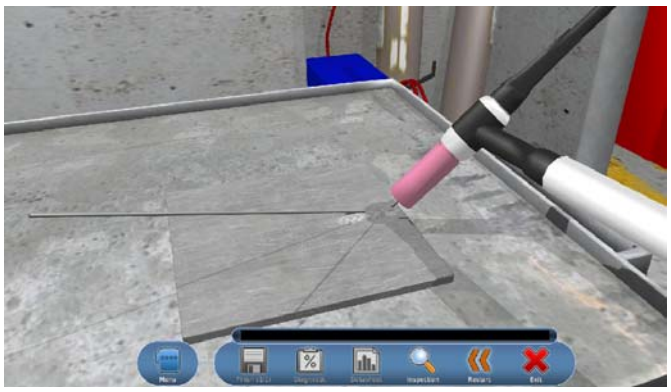

Figure 5: Virtual reality training of gas tungsten arc welding (GTAW). Source: 123 Certification Inc.

The ARC+ welding simulator allows the user to generate a virtual welder hands-on action environment with the help of patent pending technologies. It detects welder motion, processes equations between metallurgy and motion as well as casts a 3-D image of the user's gestures.

It recognizes some welding defects and their causes. While taking into account several variables affecting weld soundness, it gives the user an opportunity to evaluate his or her work with a diagnostic report, a ranking or a grade, and a visual examination as per a real welded assembly (Fig. 9). The diagnostic with a tolerance of 0.25mm RMS provides reports with motion dexterity accuracy results and some weld defects that allow the welder to take immediate corrective action, and to continuously improve his skills in a safe and enjoyable setting.

For example, we have broken down the hand motion into 5 essential variables: motion straightness, arc speed, stick-out, work angle and travel angle (Fig. 6).

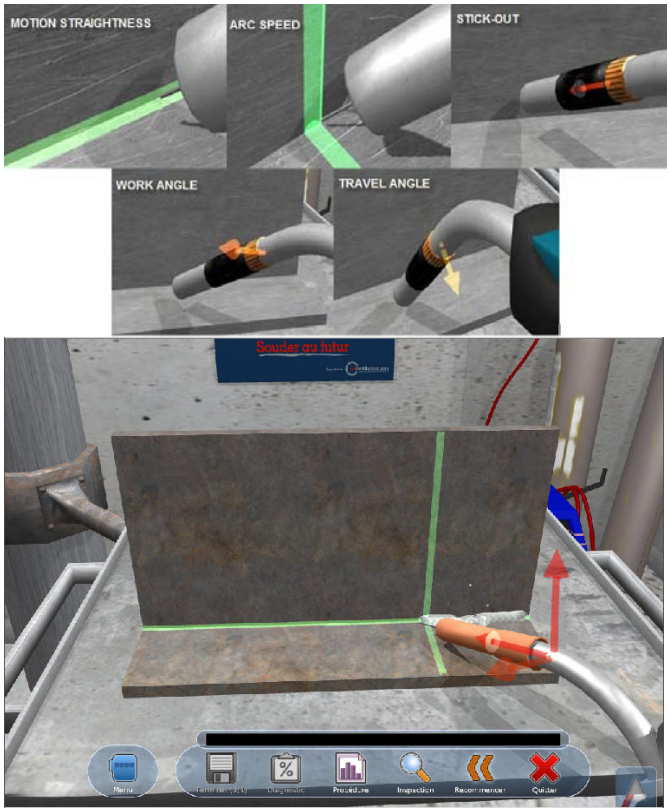

Fig 6 Five essential variables in motion dexterity that are tracked with the ARC+ simulator. Source: 123 Certification Inc.

The ARC+ simulator provides an atmosphere conducive to interactive learning thanks to numerous welding exercises based on the 5 motion dexterity variables. For example, 17 standard exercises (Fig. 7) based on those variables are available for all welding data experimentations.

In a guided training mode, a trainee would have to succeed in an exercise before stepping up to the next one. The ARC+ simulator also offers to the usual beginner, intermediate and expert, different level exercises requiring progressively more skills.

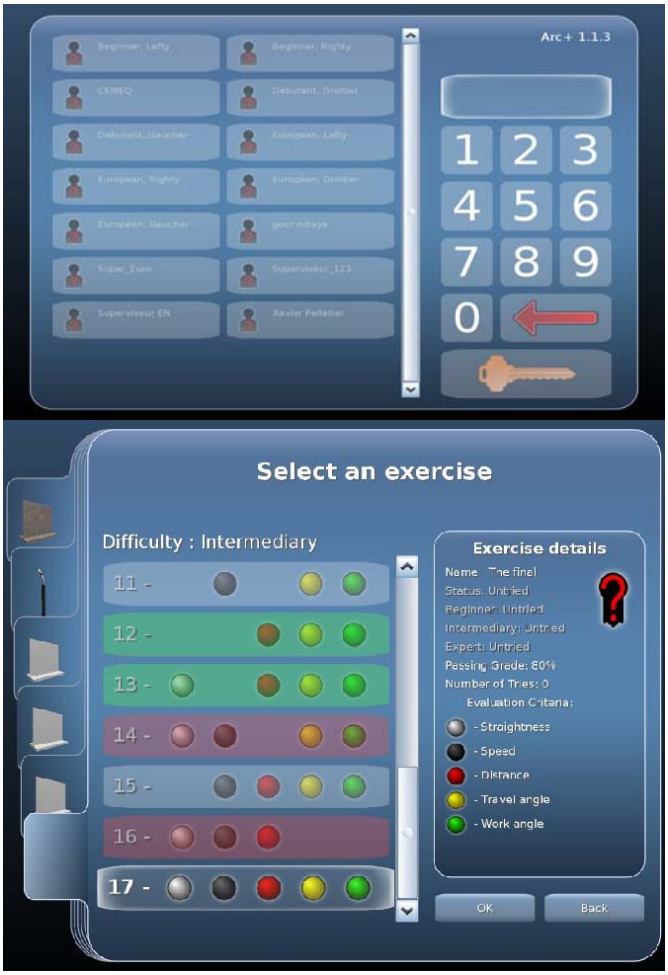

Figure 7 List of exercises based on the 5 motion dexterity essential variables. Source: 123Certification Inc.

In replay mode, an instructor can review the stick-out or the work angle in a precise location of a bead. He or she can help the student understand the weld size or the root penetration (Fig. 8). The reviews are not only for the diagnostic report but also for the motion dexterity tracked during welding. Replay can also have an unlimited angle of view to track a point on interest between the diagnostic and the welder's motion. The replay mode is a demonstration of previous trainee hands-on activities. The trainer can easily access all saved weld beads by the trainee. Trainer can easily identify and transfer to the trainee the hands-on results on the replay mode.

Figure 8 Access to replay mode for result reviews. Source: 123Certification Inc.

Figure 9: A weld diagnostic report gives immediate feedback, showing how close the student came to making an optimal weld. Source: 123Certification Inc.

BETA Phase Gas Tungsten Arc Welding

In the aircraft maintenance business, the quality requirements are extremely high. They demand particular care and a down-the-line exactness of the welded parts because they will be exposed to high temperatures in a combustion chamber of an aircraft engine.

Welders are regularly subjected by the quality control department to training exercises that make sure they fulfill contractual requirements.

The ARC+ simulator has been designed to meet these demands. For example, data from a specific welding code can be incorporated into a virtual weld procedure to ensure that the weld meets those criteria. Indeed the metallurgy diagnostic (second part of figure 9) shows heat input, weld size and root penetration. This has been called the eCertification® process and it allows welders or apprentices to perform virtual welds on of expensive light alloys such Titanium, Chrome-Molly or Cobalt. To develop hands-on reaction with precise welding parameters, the ARC+ simulator requires the same gesture control as with a real welding station. The welder has to replicate the same gestures, and those gestures have to be fine tuned in the same way as real qualification performance.

Open house at a Welding Training Centre in Eau-Claire, Wisconsin, USA

In March 2008, 123 Certification Inc participated at an Open House in Eau-Claire, Wisconsin, USA.

A newsletter item and pictures were prepared after that event:

"VIDEO GAME" TECHNOLOGY TO FILL GROWING NEED

A star attraction at Wisconsin's Chippewa Valley Technical College March 6 was the "ARC+" welding simulator demonstrated by its inventor, Claude Choquet of Montreal. Scores of professional welders, instructors, and people considering a welding career tried their hand at the simulator and got immediate feedback on their performance and aptitude. The occasion was the CVTC Weld Show open house, held on the school's Clairemont campus in Eau Claire, Wisconsin.

Many areas of North America are experiencing persistent shortages of qualified welders, even in a state like Wisconsin with a well-established network of technical colleges. Mr. Choquet and his company, 123Certification, have helped bolster the Quebec technical workforce with this invention and now offer it for export. The Wisconsin's CVTC event highlighted welding career opportunities in the fields of manufacturing, construction, and maintenance.

The simulator, which fits into its own suitcase for portability, uses advanced motion tracking technology and hi-resolution 3D rendering software for a virtual welding experience. Realistic simulated sounds, smoke, and sparks add to the experience. It's not all fun and games, however. When students have completed virtual welds, they can view previous welding sessions through replay mode and get advice from instructors who receive detailed reports on students' practice sessions.

There are a number of benefits the ARC+ simulator provides for welders, for industry, and for the environment. The simulator is used to train and qualify the skill levels of advanced welders and has the potential to be used in the re-certification process. Through repetitive training, welders can focus on continuous improvement of their welding skills yet reduce their exposure to fumes and sparks. The associated reduction in the use of raw materials not only provides cost saving benefits, but also reduces the impact on the environment.

Mr. Choquet, a welding engineer and expert in applying virtual reality technologies, has had an almost life-long interest in welding. His father, Professor Joseph-André Choquet, was an expert on weld fatigue at Polytechnique Montreal, a leading school of engineering [4].

Figure 10: Virtual reality training of gas tungsten arc welding (GTAW). Source: Chippewa Valley Technical College in Eau Claire, Wisconsin.

Figure 11: Tactile Screen is used to access the diagnostic allowing the welder to take immediate corrective action, and continuously improve his skills in a safe and enjoyable setting. Source: Chippewa Valley Technical College in Eau Claire, Wisconsin.

Methodology

The Reality

We introduce the GTAW welding method with two-hand motion capture in order to be able to simulate the weld deposition. With pictures taken at a high speed, Figure 12 shows the filler metal motion activated by the first hand and the arc's motion activated by the second hand. The motion of the first hand is responsible for the solidification wave. Uniform motions of the first hand help insure metal deposit uniformity, a key criterion for compliance with aviation requirements.

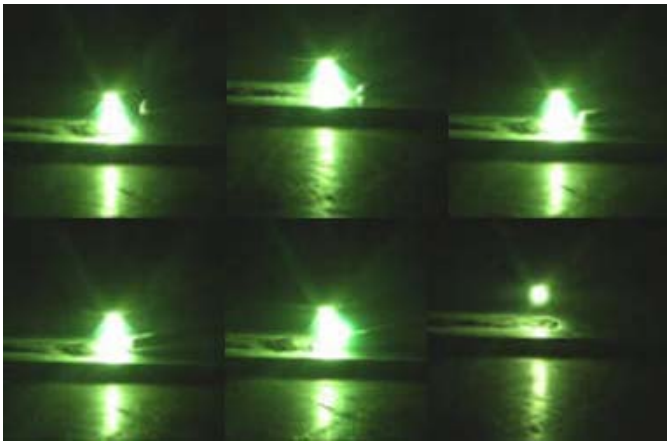

Figure 12: High Speed Pictures of GTAW deposition Source: 123Certification Inc.

Some challenges are related to the image rendering of weld pool collapsing. The work in progress is shown in the next images.

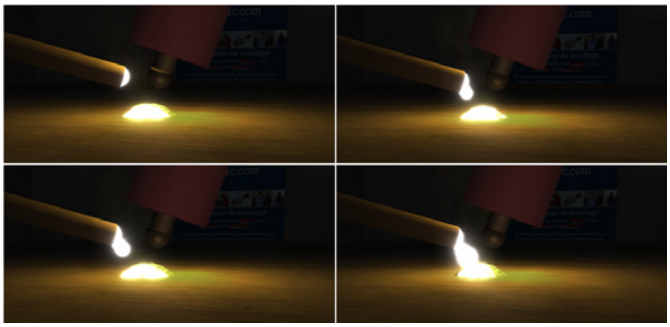

Figure 13: High Speed Images of Virtual GTAW deposition. Source: 123Certification Inc.

The motion is captured and rendered in 3D images in the glasses of the welder's mask.

Development of fine motor skills is captured, processed and posted in real time for tracking by the learner and instructor.

Results

An aerospace industry experimenting with our technology decided to do a step by step approach. The president of this family-owned company asked his daughter -with no previous welding education - to experiment with the Arc+ simulator. This first step was intended to benchmark a beginner before training. That first step being conclusive, the QC/QA manager of that company was requested to be trained. After only four (4) 3-hours sessions during which two-thirds of the trainee's time was spent on the simulator, the QC/QA manager was able to perform a linear and uniform metal deposition as required for a welder apprentice (Fig. 14). This experiment was completed without any material consumption. The positive result led to the second step which was the test made by the quality control manager. He is in charge of producing the documents attesting to the weld's integrity. The Quality Manager had never welded before and his company proposed to him a virtual training with the Arc+ welding simulator. He later went on to complete traditional factory training.

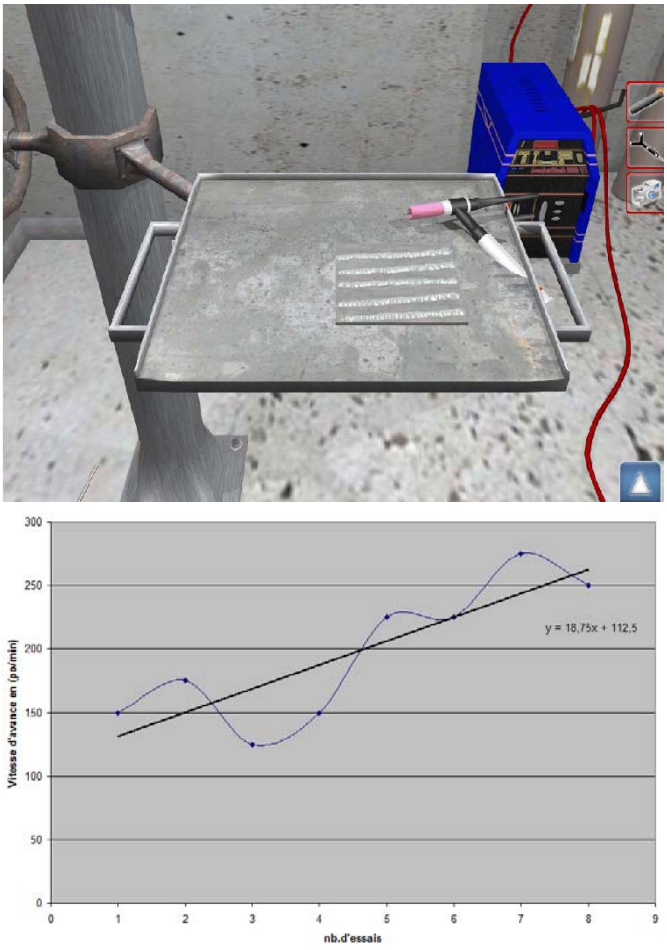

Fig 14: Virtual training welding booth and drill results from the Q4 2007 training exercise mentioned in the result section. Source: 123Certification Inc.

Conclusion

The manual and semi-automatic weding processes motion tracking along with the processing of metallurgy equations are now fully operational. The system delivers real time 3D images with all essential variables affecting the weld pool, the arc length and the welding bead without jittering, delay and drifting.

Vision for the future

The next step will be dictated by our clients, many of whom plan to increase the use of technologies which reduce unfavorable effects on the environment.

Key words

Welding, Welder, Simulation, Manual, Semi-Automatic, Gesture Control, Virtual Reality, Apprentice, Professional,

Acknowledgements

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