RESEARCH INTO THE APPLICATION OF VIRTUAL WELDING TRAINING SYSTEM (VWTS) IN CORRECTING THE WELDING TECHNIQUE OF PROFESSIONAL WELDERS

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Abstract:

As an integral part of Leonardo da Vinci partnership project InteractivWeld, an industry research was conducted in order to verify the impact of Virtual Welding Training System (VWTS) on correction and improvement of already established welding techniques of experienced GMAW professional welders. Motivation for a research was driven by the fact that significant number of welding defects is present in the production process of an involved company requiring additional repairs and rework which eventually add to increased production costs and associated throughput time. Although there are many different variables influencing the weld quality, for the purpose of this research only parameters related to GMAW welding technique and dexterity were observed. Specifically, these parameters were torch speed, torch angle and stick-out distance between torch and base material. As it was shown in this paper, after training sessions on VWTS welders show overall improvement and in average score better results on final tests in all exercises and welding procedures, which lead to conclusion that welding simulator is a powerful educational tool that, in addition to safe and inexpensive training of inexperienced workers and students, can also be used for correction of welding technique with established and experienced welding personnel.

1. INTRODUCTION

As an integral part of Leonardo da Vinci partnership project InteractivWeld, an industry research was conducted in order to verify the impact of Virtual Welding Training System (VWTS) on correction and improvement of already established welding techniques of experienced GMAW professional welders. Research was performed in company Končar – Steel Structures, a Croatian manufacturer with more than 70 certified welders producing around 7.000 tons per year of various steel structures for global customers in energy sector - with production portfolio that includes transformer tanks, generator components, aluminum busbars and train boogies. Demands for weld quality are very strict and all welds have to be verified with different non-destructive testing methods (VT, UT, PT, MT) in compliance with customers' requirements for given products.

Motivation for a research was driven by the fact that, before final shipment release, significant number of welding defects was detected and thus had to be repaired and reworked – resulting in increased production costs and associated throughput time. Most common welding defects include leakage of oil-tight welds, lack of penetration, porosity, lack of fusion, excessive welding spatter, undercutting and irregular weld shape.

Although there are many different variables influencing the weld quality – e.g. filler wire properties, shielding gas type, shielding gas flowrate, base material properties, current amperage and voltage, wire feeding speed, welding machine control algorithms – for the purpose of this research only parameters related to GMAW welding technique and dexterity were observed. Specifically, these parameters are torch speed, torch angle and stick-out distance between torch and base material.

Scope and main guidelines of the research are defined within the InteractivWeld project which introduced the term "S-K-S system" and following hypothesis:

- It is necessary to correct the welding technique of professional welders using the VWTSs in regular intervals,
- Within the same framework, it is necessary to refresh their knowledge and inform them of the latest technological achievements, and thus maintain and improve their technological know-how,
- Professional welders need to be encouraged to take up physical activity in order to raise the level of their aerobic abilities for performing such difficult jobs, and to achieve the level of psychological abilities to carry out their professional activities in all possible situations.

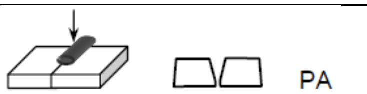
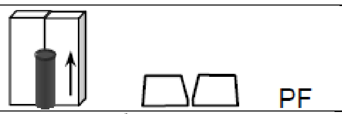
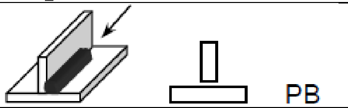
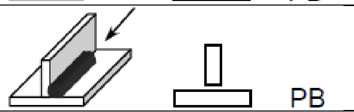
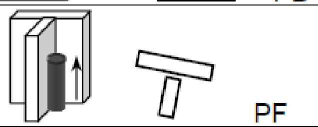
2. METHODS

For purpose of testing and improving the aforementioned technique parameters (torch speed, torch angle and stick-out distance) special Virtual Welding Training System (VWTS) was used. It is designed and produced in one of the world's leading producer of welding machines - Fronius from Austria. Fronius VWTS is a machine designed with a goal to simplify and improve the training of welding personnel and it is primarily aimed at students and workers without prior welding experience. Its user friendly interface and evaluation scoring of working sessions opens the possibility to make trainings with significantly reduced costs as there is no necessity for both filler and base materials consumption.

Picture 1. *Fronius Virtual Welding Training System (VWTS) in practice session*

During the research VTWS machine was used with professional welders in order to check their existing technique and to improve it through subsequent training sessions. 20 GMAW welders with different age, constitution and personality traits were chosen and led through special training program adapted for most commonly used welds in everyday practice. There were 5 different welding procedures used throughout the research – with varying plate thickness, welding position and number of layers included. Simulated base material was mild steel S235JR and filler material was wire electrode G3 Si1 with 1,2 mm outside diameter. More detailed overview of five chosen procedures is described in Table 1.

Table 1. *List of evaluated welding procedures*

Evaluated welding procedures		
1	Plate, t=15 mm, BW, PA, ml (3 layers) - MAG	
2	Plate, t=15 mm, BW, PF, ml (2 layers) - MAG	
3	Plate, t=10mm, FW, PB, sl - MAG	
4	Plate, t=10mm, FW, PB, ml (3 layers) - MAG	
5	Plate, t=10mm, FW, PF, ml (2 layers) - MAG	

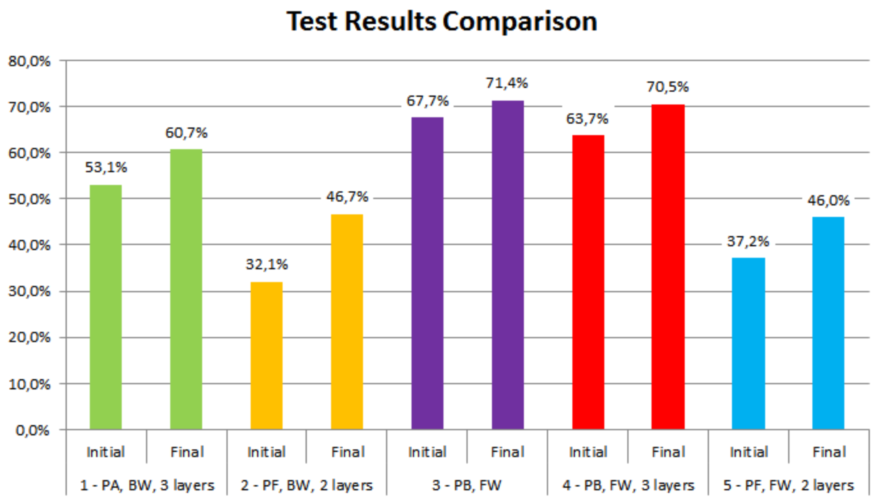
At the beginning of the training session each welder has made an initial testing for all five welding procedures, where achieved results were noted and later used for progress evaluation. After initial testing, which lasted around 1 hour per welder, series of training sessions for all procedures were conducted with supervision from authorized personnel. Each welder was awarded with 3 hours of training session. Finally, after all training sessions were completed, there was a final evaluation lasting around 1 hour per welder. Results from initial and final sessions were then used to compare progress of each individual welder in different scoring categories – i.e. torch speed, torch angle and stick-out distance for each individual welding procedure. In total each welders made 2 tests and 1 training session consisting of 11 passes, which in total gives 660 results used for later evaluation and analysis. Each welder spent around 5 hours for all of these tests and trainings.

Picture 2. *Welders during training session on VWTS*

In addition to welding on virtual simulator (VWTS) five welders welded real samples according to the 5 WPS's given in the course. These samples were welded both before and after the exercise on simulator and after the welding, samples were tested visually and with NDT using penetrants.

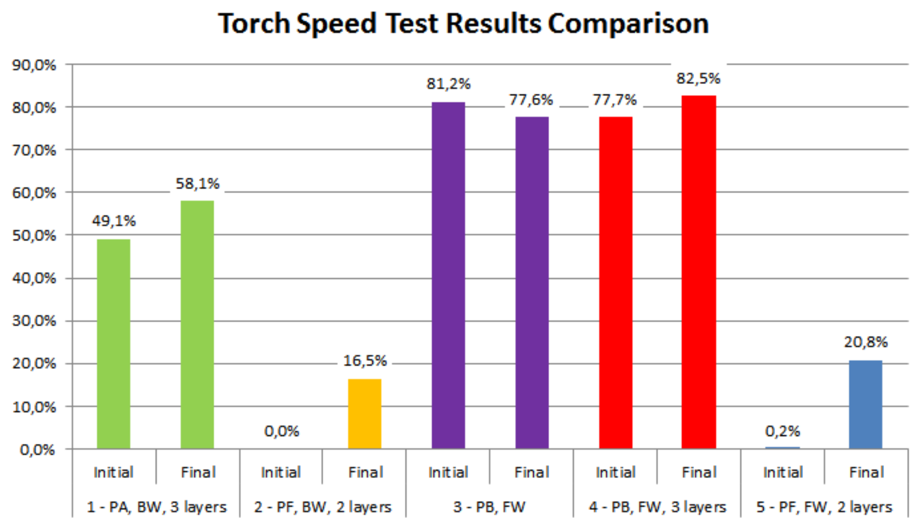
3. RESULTS

Although there were variations between evaluation results of individual welder in different tests and parameters, in general there is a significant improvement in their welding technique when final results are compared to those from initial testing – as seen on picture 3. Individually improvements were linked to some of the psychological traits of the welders, as younger ones in average adapted better to required changes to their usual welding technique. When comparing the different welding procedures, biggest improvements were seen in WPS number 2 (2-layered butt weld in PF position +14,6%) while least improvement was noted in WPS number 3 (single-layered fillet weld in PB position +3,7%). Respectively, these weld types had best and worst average results during the initial training sessions (WPS 2 had score of 32,1% and WPS 3 had 67,7%).



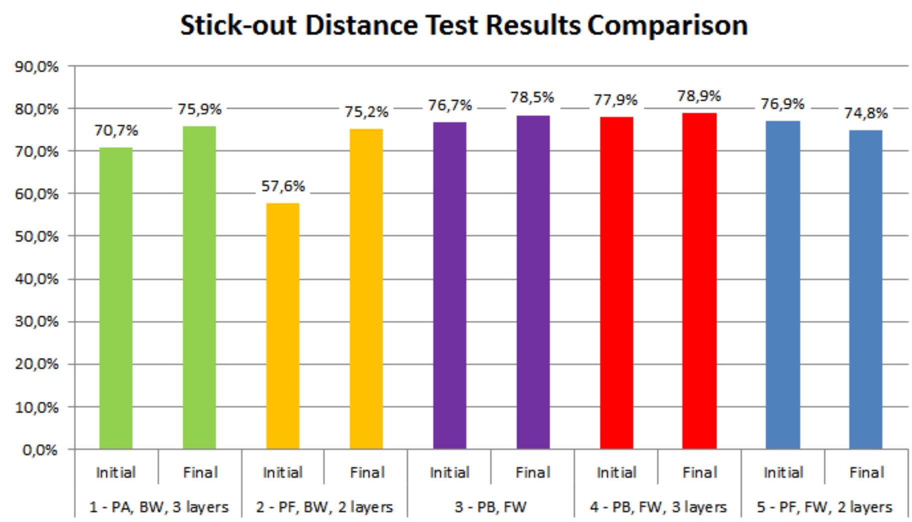
Picture 3. *Comparison of average test results for all 5 welding procedures*

When welding technique parameters are individually observed, stick-out distance had the best initial scoring results, followed by torch angle and welding speed. There was an unusual discrepancy between average results in welding speed for different WPSs – specifically in PF positions (Picture 4) – which can be explained through biggest difference in real-life welding and simulation of welding in PF position, leading to slower adaptation of professional welder to suggested welding speed parameters in VWTS.



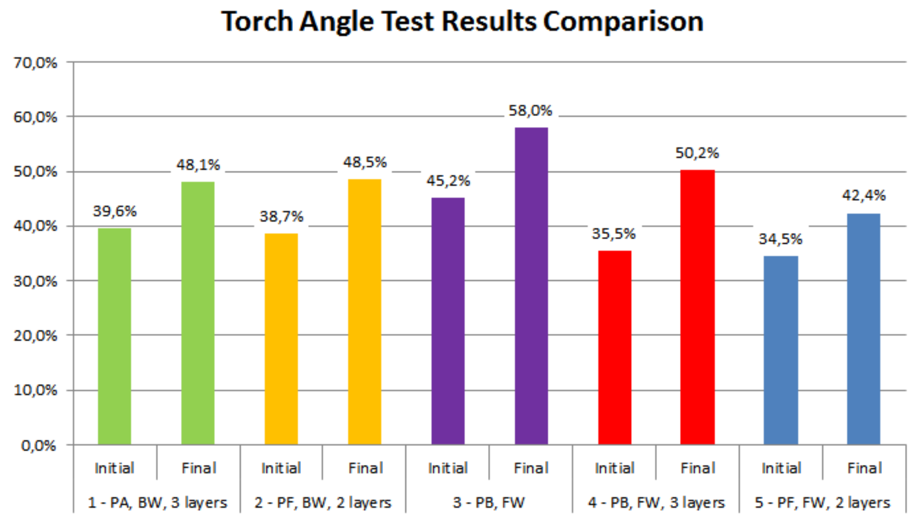
Picture 4.*Comparison of average torch speed results for all 5 welding procedures*

Stick-out distance between welding torch and base material had best initial results during testing and least improvement during the training sessions. Again, exception are the results for WPS 2 (Picture 5), where significant improvement was made (+17,6%). Conclusion is that welders already used the near-optimum stick-out distance during the real welding operations, thus limiting the potential for improvement during the training sessions.



Picture 5. *Comparison of average stick-out distance results for all 5 welding procedures*

On the other hand, biggest correction of welding technique was made in torch angle category (Picture 6). In GMAW welding optimum torch angle is one of the critical parameters for correct gas shielding functionality. Incorrect torch angle can cause porosities in welds – an error common in everyday operations of researched company.



Picture 6. *Comparison of average torch angle results for all 5 welding procedures*

At the end of the research, visual and NDT comparison of welded samples was conducted and for some welders there was a significant improvement in surface condition of observed welds.

Picture 7. *Comparison of welded samples for WPS 5 (fillet weld in 2 layers)*

4. CONCLUSION

Although welding simulators are ideal tools for introduction of students and workers without prior welding experience to welding techniques, there are some aspects of the techniques that can be applied also with experienced welders in real-life welding operations. Increasing the awareness of making errors on simulator and consequent improvement of self–control can have big impact on welders' state of mind during real welding, thus improving the overall weld quality.

As it was shown in attached graphs, welders show overall improvement on simulator and in average score better results on final tests in all exercises and welding procedures. Biggest improvements are seen in the area of holding the right torch angle to base material and with younger welders that were still eager to accept the proposed corrections and applied them to everyday operations.

Finally, considering all the analyzed data and reactions from welding professionals, there is a common conclusion that welding simulator is a powerful educational tool that, in addition to safe and inexpensive training of inexperienced workers and students, can also be used for correction of welding technique with established and experienced welding personnel.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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