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ADVANCED FUNCTIONS OF MODERN POWER SOURCE FOR GMAW WELDING OF STEEL

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Abstract:

This article is focused on evaluation of use of modern welding power source equipped with advanced functions of arc control. At the Laboratory of welding technologies of CTU in Prague we have focused on GMAW welding of steel using modern welding power source produced by Migatronic – Sigma Galaxy equipped with functions called Intelligent Arc Control and Sequence Repeat. Controlling arc by these functions should according to manufacturer significantly stabilize welding process, lower heat input, deformation and improve weld quality. To completely evaluate benefits of these functions, single V butt welds were done on S275 J2 of 10 mm thickness (2 weld layers root + covered weld) in PF and PG positions. Welding was monitored by Welding Information System and compared with standard GMAW welding. Results have shown that these "intelligent" functions offer significant advantages for welding of steels, especially in vertical position PF.

Keywords: Welding; GMAW; IAC, Sequence Repeat

INTRODUCTION

Aim of this research is to understand main advantage of using modern GMAW welding source equipped with special pulse control welding functions. To measure and present influence of pulse control and to compare independent experimental results with information advertised by welding source manufacturer is the main goal.

At the present industrial welding praxis, GMAW (Gas Metal Arc Welding) is the most widely spread welding technology. As for any manufacturing technology, industry demands from GMAW welding process increasing efficiency, economy and welding speed while keeping the weld quality high (improved) and lowering demands on welders' qualification. Another industrial needs put on GMAW process are e.g. welding in overhead (PF, PE) and vertical positions (PF, PG), bridging wide root opening, increase in melting rate. On of important trends is also to apply GMAW in domain of GTAW welding, i.e. welding of high strength steels, welding of non-ferrous materials and heterogeneous joints.

Development of modern microelectronics has enabled fast development of welding sources. By use of fast microelectronic circuits, speed of welding process control and welding parameters adjustment was increased tremendously, thus dynamic control over arc and molten metal transfer. Research and development done by welding sources manufactures is basically focused upon simultaneous optimal control of welding parameters during welding. The modern welding sources are equipped with special control functions of arc and molten metal transfer focusing on 2 basic areas. First area of focus is welding of thin metal sheets (0.5-3 mm) and the second high productivity thick metal sheets welding.

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1. Thin metal sheet welding – Highest priority in thin metals welding is to stabilize and lower heat input to reduce risk of burn-through, to reduce warping, improve melt pool control, lower spatter. This can mainly be reached by stabilizing and controlling arc. With this in mind, many welding sources manufacturers have developed pulse control functions incorporated into their welding sources, e.g. CMT (Fronius), STT (Lincoln Electric), Cold Arc (EWM), SAT (Esab).
2. Thick sheet welding – Highest priority is in maximizing weld metal deposition rate when heat input and spatter is low. For sheet over 5 mm welding sources with functions as e.g. Force Arc (EWM), Power Arc (Migatronic), Aristo SuperPulse (Esab) tandem welding, T.I.M.E. (Fronius) can be shown [1,6].

For our research Migatronic welding source Sigma 400 Galaxy equipped with function IAC (intelligent arc control) and Sequence Repeat was used. Short introduction of these functions advertised by Migatronic is being shown:

Function IAC – Intelligent Arc Control

This function is specially focused on welding of thin sheets and root welds, bridging wide and uneven weld gaps, welding in vertical downward PG position. Function offers lower spatter, high stability, low heat input. IAC function is changing standard short arc current and voltage evolution. During molten metal drop separation, when short circuiting is finished, the current pulse with low value is used to suppress significantly spatter [2,3].

Function Sequence Repeat

This function is combining 2 molten metal transfer modes cyclically, e.g. combination of short arc and pulsed transfer mode. Short arc has lower welding parameters (less heat input) and pulsed transfer mode has higher parameters (higher heat input). This is advantageous welding in difficult positions PC, PD, PE, PF or PG. When applied to V-joint butt weld, welder can do weave movement without dwell over beveled face. Usually this dwell is needed to distribute heat as necessary. Pulsed transfer is used when torch is over beveled faces (to assure side wall fusion), short arc is used when not (central part of the weld, to prevent excessive reinforcement). Thus continuous weave movement is possible, making weave movement for welder easier [2,4].

EXPERIMENTAL

Robotic welding was done at robotic cell at welding laboratory of CTU in Prague equipped with power source Migatronic Sigma 400 Galaxy, equipped with IAC and Sequence Repeat functions was used. Evaluation of improvement caused by use of functions IAC and Sequence Repeat was based on comparing samples A and B welded in difficult vertical positions PF, PG. Sample A was welded using these functions, the sample B was welded without their use, using typical welding parameters and short arc transfer mode.

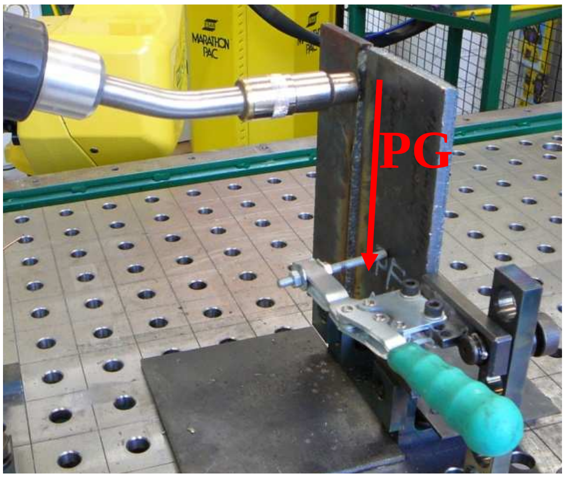

Fig. 1 Weld sample-welding position PG

Sample thick 10 mm needed 2 layers, root layer and capping layer done with weave function. To observe evolution of U, I in time, monitoring unit „WIS“ (Welding Information System) was connected to welding source to record time evolution of welding parameters I, U, v, etc.

Root weld was done in vertical downward PG position for sample A and B, at fig. 1. PG position is considered difficult position for root welds because it does not offer good penetration and often has problem of insufficient root penetration. Capping layer was done in vertical upward position PF.

Structural steel S275 J2 thick 10 mm was used. Composition and basic properties are at tab. 1. Typical filler material for these steels from Esab, OK Autrod 12.56, diameter 1 mm, was used. Base metal sheet size is 200 x 80 mm, thickness 10 mm, was used. V-joint with groove angle 70° and root opening 3,2 mm. Shielding gas is M21, mixture of 82% Ar + 18% CO_2.

Tab. 1 Base metal composition and mechanical properties- S275 J2 [5]

C	Mn	Si	P	S	Al
Max. 0.22%	Max. 1.6%	Max. 0.55%	Max. 0.035%	Max. 0.035%	0.01 – 0.06%
R_m		$R_{p0,2}$		A_5	
410 - 560		275		21%	

RESULTS

Welding parameters used for samples A, B are stated in tab. XX. Setting optimum parameters for A sample was easier, already 1st sample was successful. Creating good weld without advanced functions, with standard short arc needed 3 B test samples.

Root weld - Welding parameters setting

To create sound weld it was necessary to adjust welding parameters especially for sample B. Welding parameters are welding speed 0.10 $m.min^{-1}$, current 80 A, voltage 16 V, weave movement setting: frequency 2 Hz, amplitude 1.5 mm, dwell 0.4 s.

Sample A: Function IAC was used with upper stated parameters. Weld had sufficient root penetration and at both faces as well, at fig. 4. Arc was stable. Molten pool was not dripping. No spatter was found. Weld quality is high without defect.

Sample B:

When current 80 A was set up on the welding source without using IAC function, the welding process was very unstable. Arc was unstable, heat input was insufficient, joint faces not completely fused. Only 1 joint face was melted. To stabilize process and to fuse both join faces, current was needed to be twice increased to 100 A and 130 A. At 130 A welding process was stabilized, but the root of the weld have concave shape (welding defect: root concavity) as visible at fig. 6. This is in concordance with known fact, that short arc in PG position is not suitable for root weld. PF position would be more suitable.

Capping weld - Welding parameters setting

Capping welds were done in vertical upward PF position.

Sample A: Function Sequence Repeat was used for capping layer. Function Sequence Repeat was changing metal transfer mode periodically from IAC short arc to pulse transfer, as visible at fig. 3. Setting of function was: IAC short arc transfer 85 A for period 0.6 s, pulsed arc transfer 150 A for period 0.3 s. Result at fig. 5.

During phases of pulsed arc (higher heat input), torch was heating up weld faces. During IAC short arc (lower heat input), torch was in between faces.

Sample B: To melt both joint faces well, the current was needed to be increased to 145A. Result visible at fig. 7.

Welding parameters that have been set are shown in tab. 2.

Tab. 2 Welding parameters

Sample	Function, metal transfer	Weld pass	Current [A]	Voltage [V]	Wire feed [m.min^{-1}]	Welding speed [mm.s^{-1}]	Heat input [kJ.mm^{-1}]	Result
A	IAC	root	80	15,5	2,5	1,7	0,59	OK Fig. 4
	Sequence Repeat	capping	85short arc 150 pulsed	16 26,4	2,6 6,7		0,66 (0.3 s) 1,90 (0.6 s)	OK Fig. 5
B1	Short arc	root	80	16,3	2,5		0,63	NG
B2	Short arc	root	100	17	3,3		0,82	NG
B3	Short arc	root	130	18,5	4,9		1,16	OK Fig. 6
	Short arc	capping	145	19,2	5,6		1,34	OK Fig. 7

Measured time evolution of current and voltage for root weld of sample A and sample B3 is shown at fig. 2. At this picture the difference of standard short arc transfer and IAC function short arc transfer is easily visible.

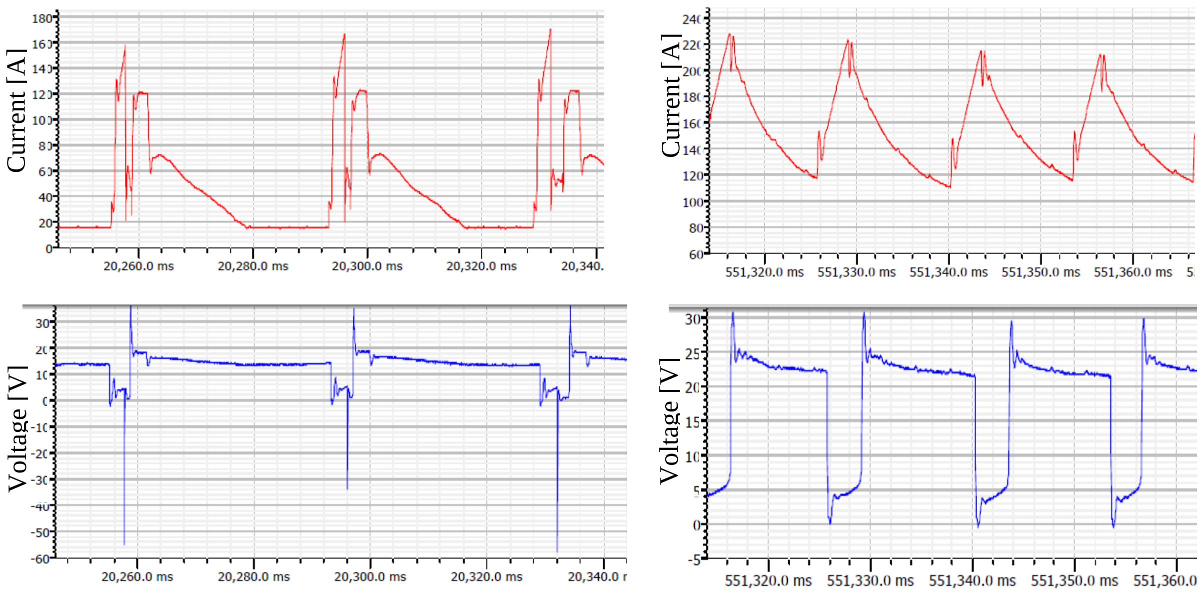

Fig. 2 Current, voltage time evolution for root weld – Left: Sample A- IAC function 80 A, Right: Sample B- short arc transfer 130 A

Short arc transfer (right side) - when metal drop touches the weld pool, current raises to maximum values, voltage drops to 0 V. During short cutting there is no arc and current is increasing to maximum value limited by the power source.

Using IAC function (right side), the voltage and current time evolution is distinctly different from standard short arc. The current is rising during the shortcut, but power source after certain time sharply decreases voltage, by which current is also decreased. This sharp energy drop slower down melt drop transfer and spatter is reduced significantly. The voltage and current are raised again to start arc again.

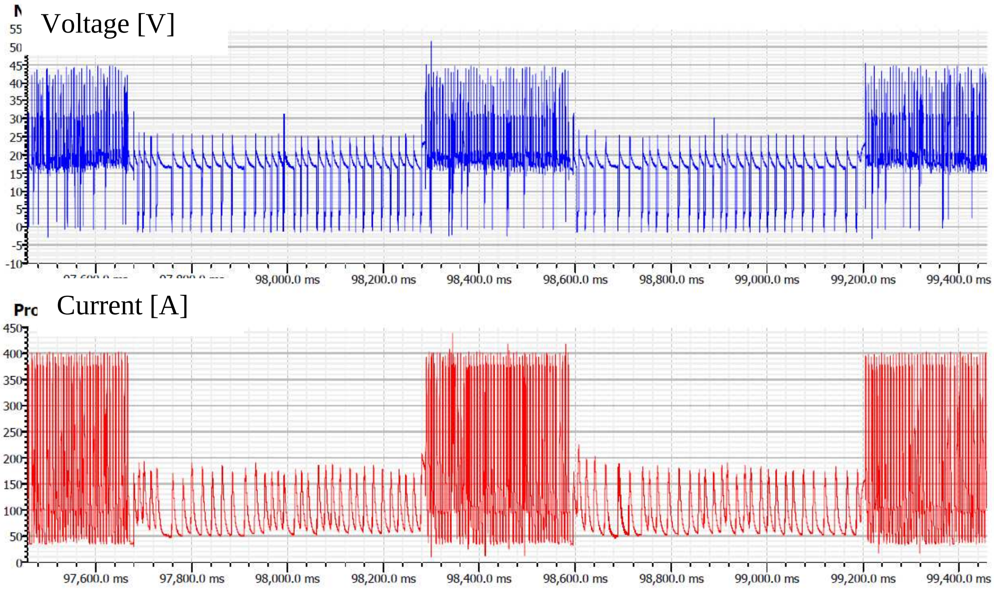

Fig. 3 Current, voltage time evolution for Sequence repeat weld

Tab. 4 Measured weld geometry

Sample	Weld width [mm]	Weld reinforcement [mm]	Root width [mm]	Root reinforcement [mm]	HAZ width [mm]
A	11	1,9	4	0,3	14
B3	12	1,8	6	-0,5	16

Weld geometry for sample A, B are shown at tab. 4. The lowest width of the HAZ at root was measured for sample A, welded with IAC function (80 A), 14 mm. Sample B for the same current (80 A) did have lack of penetration and lack of fusion and when the current was increased to 130 A, than HAZ size increased to 16 mm.

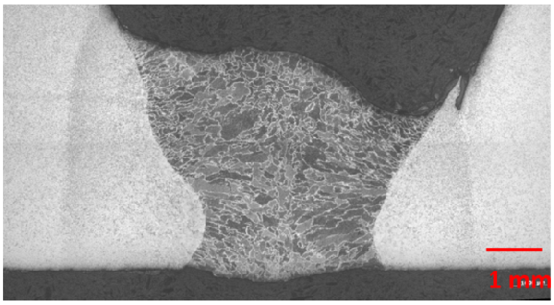

Fig. 4 Sample A – root welded with IAC 80 A

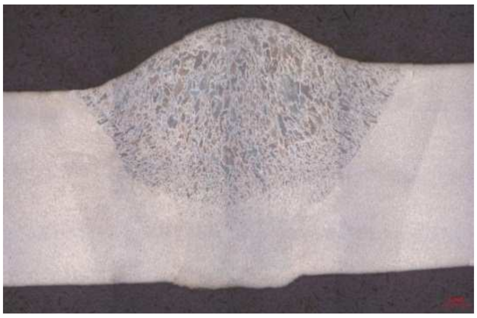

Fig. 5 Sample A – capping layer welded with Sequence repeat 85 A/150 A

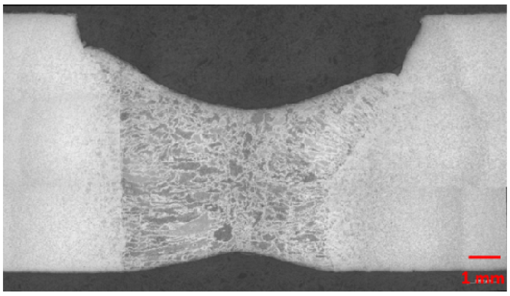

Fig. 6 Sample B3 – root weld, short arc 130 A

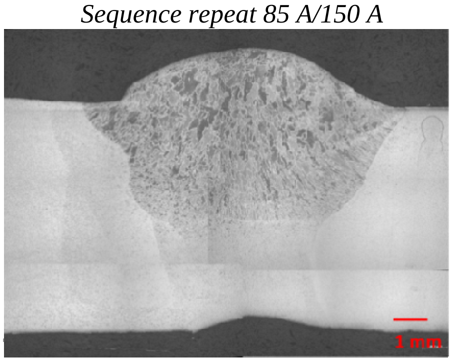

Fig. 7 Sample B3 –capping layer, short arc 145 A

CONCLUSION

The experiment affirmed advantages of IAC function short arc to standard short arc for welding in difficult positions (PG), because the improved root shape. IAC function controls voltage and current so that heat input into the weld can be much lowered. The arc is much more stable even for low arc parameters. The fact that heat affected zone is smaller and spatter is suppressed has been proved.

Function sequence repeat is advantageous for filling, capping weld passes because lowering total heat input by controlling voltage and current evolution. Good weld was gained in PF position, heat affected zone size was reduced compared to standard short arc weld.

The development of electronics and programing has enabled creation of special functions that can very well improve behavior of arc and melt transfer, making the welding stable with lower parameters. These functions certainly improve some aspects of welding process and they also make welding easier for welders, by facilitate parameters setting, welding in difficult positions etc.

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