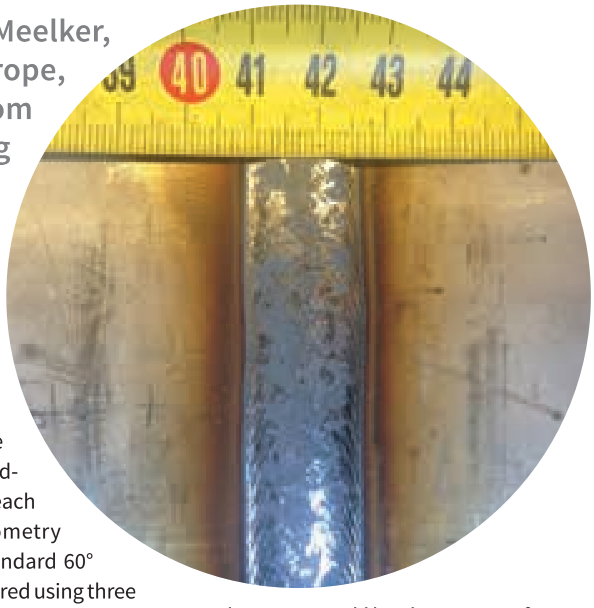
Rapid-X welding process technology

In this article by D Ritsema, R van Klooster, H Meelker, D Senogles and P van Erk of Lincoln Electric Europe, new Rapid-X™ welding process technology from Lincoln Electric is shown to improve welding productivity for stainless steel process pipe, increasing welding speed by 15% while reducing heat input by 20%.



The cap pass weld bead appearance from Lincoln Electric's Rapid-X process.

It is well known that the deposition rate of traditional constant voltage (CV) MIG welding can be increased simply by increasing the wire feed speed. However, this is only feasible if the welding process can be kept stable enough for high quality welds to be produced. Also, higher deposition rates are often accompanied by higher arc energies, which can impact negatively on the mechanical properties of both the base material and deposited weld metal.

The new synergic pulsed-MIG welding process from Lincoln Electric, Rapid-X™, has been developed to allow higher usable wire feed speeds compared to conventional pulsed-MIG welding. The Rapid-X process operates with a shorter arc length, which enables significantly higher travel speeds and therefore significantly reduced arc energies. In addition, the lower arc voltages associated with Rapid-X mean that the process is more resistant to undercut.

In this study the Rapid-X process was compared to conventional pulsed-MIG welding and flux-cored arc welding (FCAW) for mechanised fill and cap pass welding of stainless steel process pipe. All root-pass welding was carried out using Lincoln Electric's proprietary STT® process.

STT® + Rapid-X™		
Test	**Result**	**Comment**
Cross weld tensile test	583 MPa	Break pipe
	565 MPa	Break pipe
Root bend	Acceptable	No defects
	Acceptable	No defects
Face bend	Acceptable	No defects
	Acceptable	No defects
CVN -196°C	34 J avg	Size 5×10 mm
LE -196°C	0.96 mm avg.	

Table 1: A summary of the mechanical rest results for the pipe butt welds completed using different process combinations.

Welding procedures

ASTM A312 TP304L Sch. 40S (323.9 OD×9.53 mm) pipe was used for all welding procedures. In each case, the joint geometry was an industry standard 60° V-joint that was secured using three bullet tack welds.

All the consumables uses were standard, commercially available grades. The solid-wire welding procedures were completed using an ISO 14175-M12 shielding gas (96% argon, 3% carbon dioxide and 1% hydrogen). In the case of flux-cored arc welding, the shielding gas applied was an ISO 14175-M21, consisting of 80% argon and 20% carbon dioxide.

For STT root pass welding, the root-side was protected using an ISO 14175-F5 backing gas of composition 95% nitrogen and 5% hydrogen. A Walter Schnorrer WS 300 system was inserted into each pipe joint for gas purging prior to and during the welding of all passes.

The welding parameters for each process were carefully optimised to give the best welding performance for this particular application. All STT root pass welds were deposited manually, in rotated pipe, using a non-synergic welding mode where peak current, background current and wire feed speed could be changed independently. Manual STT welding allowed the welder to quickly accommodate for variations in root gap as well as deal with any 'hi-lo' in the joint set-up.

A mechanised welding solution was applied for all fill- and cap-pass welding, again in rotated pipe. Here the welding operator could adjust the contact tip to work distance, the wire position in the joint, as well as the weave width during welding. As can be seen in Figure 1, this resulted in a cosmetically appealing weld bead that was optimised from the standpoint of productivity and quality.

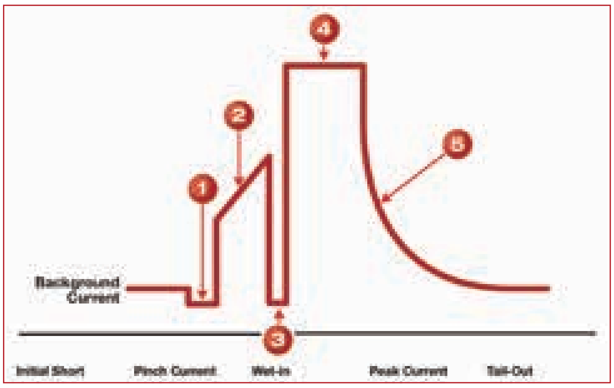
Each pipe butt weld was subjected to mechanical testing to examine the cross-weld strength via tensile tests, the ductility and fusion via bend tests, and the weld metal toughness via sub-size Charpy V-Notch tests. In the case of austenitic stainless steel weldments, lateral expansion is often specified as a code requirement and so this test was included for completeness. The results for all these mechanical tests are summarised in Table 1.

Welding productivity

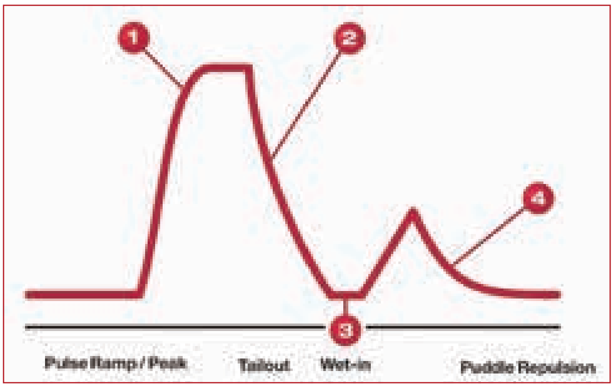
Each butt weld consisted of a manual STT root pass together with one mechanised fill- and cap-pass. A summary of the actual travel speed and calculated arc energy for the weld passes is provided in Table 2 and in Table 3, where the same data has been converted to show percentage changes to compare Rapid-X to the other welding processes.

It can be seen that, on average, the Rapid-X process resulted in travel speeds that were 15% higher compared to conventional pulsed-MIG welding and flux-cored arc welding in this investigation. The higher travel speeds and lower arc voltages associated with Rapid-X yielded, on average, a 20% reduction in arc energy.

The significantly lower arc energy of the Rapid-X process resulted in a much



The STT waveform.



Rapid-X waveform.

narrower and less intense heat-tinted zone on the root-side of the pipe.

The Rapid-X weld passes were deposited using higher wire feed speeds compared to conventional pulsed welding, however, these speeds were not associated with higher welding currents. This is another key advantage of the Rapid- X process.

Lincoln Electric's advanced power sources

The welding processes used in this comparative study are available as standard from Lincoln Electric when using Power Wave® S350 or S500 power sources in combination with digital STT® modules. A short summary of the characteristic features of these welding processes are presented below.

STT is a waveform-controlled, short circuit transfer process that allows welding current to be set independently of wire feed speed. The arc voltage is continually 'sensed' so that timely and precise amounts of current can be delivered to the arc (Figure 3) thereby reducing spatter and fume significantly. STT produces sound root welds with low heat input, but without the risk of lack of fusion.

Since an STT root bead can approach 5.0 mm in thickness, the first fill pass can be accommodated using higher energy processes, such as submerged arc welding, without the risk of burn-through. Typically, an STT root bead can be deposited four times faster than tungsten inert gas (TIG) welding. In addition, the time required for a welder to learn to produce sound welds with STT is significantly reduced compared to TIG welding.

Rapid-X is a waveform-controlled, synergic pulsed welding process that operates with a shorter arc length compared to both traditional constant voltage (CV) spray arc welding and conventional pulsed MIG welding. The Rapid-X process actually uses the STT module to provide low current wet-in (Figure 5) to produce spatter-free welds.

Peak current values are carefully controlled to ensure sufficient energy to allow high travel speeds while maintaining excellent sidewall fusion and penetration characteristics. Originally developed for high-speed lap joint welding in the automotive industry, Rapid- X is now being applied for welding applications in a wider range of market sectors.

Unlike constant voltage (CV) spray arc welding where current values remain continually high, conventional pulsed-MIG welding involves rapid modulation of the current between (high) peak and (low) background values to produce a tightly controlled droplet transfer regime in which individual droplets are 'fired' across the arc. The result is a very stable arc, with lower heat input, that facilitates all-position welding capability on both thick and thin materials.

Conclusions

In this study a new synergic pulsed-MIG welding process from Lincoln Electric, Rapid-X, has been compared to conventional pulsed-MIG welding and flux-cored arc welding (FCAW) for mechanised fill- and cap-pass welding of stainless steel process pipe.

In this particular application, Rapid-X was found to offer a 15% increase in travel speed while simultaneously reducing arc energy by 20%. Both of these results are directly related to the lower arc voltage and fast following characteristics inherent in Rapid-X technology.

The significantly lower arc energy of the process was found to give a much narrower and less intense heat-tinted zone on the root-side of the pipe. Such effects are expected to have a positive effect in terms of preserving corrosion resistance for stainless steel materials.

	Welding speed (cm/min)		Heat input (kJ/mm)	
	Fill	Cap	Fill	Cap
Rapid-X	33,5	29,8	0,9	1,0
Pulsed MAG	27,0	27,8	1,2	1,2
FCAW	27,4	28,4	1,2	1,3

Table 2: A summary of the actual travel speed and calculated heat input for weld passes completed using different processes.

	Welding speed		Heat input	
	Rapid-X vs Pulsed	Rapid-X vs FCAW	Rapid-X vs Pulsed	Rapid-X vs FCAW
Fill	+24%	+22%	-25%	-28%
Cap	+7%	+5%	-12%	-19%
Average	+16%	+14%	-19%	-23%

Table 3: Percentage changes in travel speed and heat input energy of Rapid-X compared to the other welding processes.

STT root-pass welding.

Mechanical test data shows that Rapid-X is capable of producing high-strength, high-toughness, and high-quality weldments that comfortably meet typical code requirements for cryogenic welding applications.