A hybrid methodology for orbital pipeline welding

This white paper by Laurent Baudouin and Francesco Ciccomascolo of voestalpine Böhler Welding presents results of comparative orbital pipe welding trials based on using conventional V-Bevel weld preparations. A hybrid girth welding method using the company's mechanised pipeRunner® bug and band system for fill and cap passes was compared to manual SMAW welding for all passes. In both cases, SMAW welding was used for the root and hot passes.

Welding operations for onshore pipelines focus primarily on girth welds for joining pipe-to-pipe. The predominant material for these pipes is often unalloyed and low-alloyed steels and, in such cases, manual shielded metal arc welding (SMAW) employing cellulosic electrodes remains the prevalent choice.

While gas metal arc welding (GMAW) mechanisation is already well-established in this domain – characterised by a sophisticated approach involving narrow grooves cut using on-site bevelling machines and internal line-up clamps, and welded using advanced bug and band systems – there is growing interest in a 'hybrid' solution. This hybrid approach seeks an optimal balance between flexibility, ease of use and productivity, relying on bug and band systems and rutile flux-cored wires (FCAW).

The hybrid methodology

In this hybrid girth welding methodology, fill and cap welding are executed with uphill progression using a conventional V-bevel joint preparation and rutile flux-cored welding (FCAW) wires. The root and the hot (2nd) pass are initially performed through SMAW, but in some specific cases, Gas Tungsten Arc Welding (GTAW) or Gas Metal Arc Welding (GMAW) may be preferred.

This hybrid approach offers several advantages compared to the downhill welding technology, which typically uses solid wires in a narrow gap:

- **Flexibility:** The hybrid solution allows for greater adaptability in welding operations, accommodating variations in project requirements and conditions.
- **Ease of use:** The methodology is designed to be user-friendly, simplifying the welding process and enhancing operational convenience.
- **Productivity:** Despite the ease of use, the hybrid approach does not compromise productivity, providing efficient and effective welding solutions.

The combination of bug and band systems and rutile FCAW presents a compelling alternative, addressing the specific challenges of onshore pipeline welding while leveraging the benefits of the uphill welding techniques.

The hybrid solution stands as a pragmatic compromise that optimises the welding process in terms of performance, versatility, and operational simplicity.

However, there are certain drawbacks to the hybrid approach. Despite a substantial deposition rate per pass, the hybrid process tends to be slower than the downhill procedure, which impacts overall welding efficiency. Also, the presence of slag from the flux impedes the use of double torch equipment, which can reliably be used in narrow gap weld grooves with solid wires to further improve the productivity.

Mechanical properties, especially weld-metal toughness, may be lower due to higher heat input with the hybrid process, and the use of fine-tuned welding consumables such as Böhler Welding's specialised diamondspark RC-pipe range of flux-cored-wires for pipelines is necessary to mitigate these effects.

Having to fill a V-bevel instead of a narrow gap also results in higher filler metal consumption, which influences consumable the costs.

On the positive side, the hybrid approach offers several advantages. The hybrid method requires less investment in equipment compared to the complex downhill procedure. It eliminates the need for a site bevelling machine and internal clamp, which streamlines the welding preparation and setup. A single set of welding parameters and a simpler, less expensive bug and band system contribute to operational ease, while the hybrid approach is inherently more operator friendly, reducing the complexity of the welding procedures.

Most importantly, compared to the downhill process, the hybrid process is less sensitive to lack of fusion and porosity, resulting in far fewer indications from post-weld non-destructive testing (NDT) – zero indications in cases where the procedure is carried out diligently.

In summary, while the hybrid approach introduces certain challenges, its advantages in terms of equipment cost, simplicity, and operator ease make it a

In combination with diamondspark flux cored wires, Böhler Welding's pipeRunner® for pipeline welding can deliver flawless girth welds with excellent material properties.

viable and attractive option for onshore pipeline welding, especially when considering trade-offs in deposition rates and mechanical properties.

In comparison with all passes being completed using SMAW electrodes, the hybrid option presents several advantages, including: improved productivity due to higher travel speeds and deposition rates; reduced downtime due to the continuous workflow associated with using the a pre-programmed bug-and-band system for the more time consuming fill and capping runs; high consistency, quality and repeatability; and much lower repair rates due to porosity or lack of fusion indications.

To fully realize the potential benefits, however, it is imperative to use flux-cored wires specifically designed for pipeline applications for the fill and capping runs. These provide proper support to the weld bead, especially in the critical positions between 6:00 and 4:00 o'clock. Typical consumables include: diamondspark 52 RC or one of the diamondspark X60 to X80 pipe range of consumables, depending on the base metal pipe specifications.

Another essential component of this Hybrid solution is a bug and band system that is fully programmable, digitally controlled, and offers high precision welding arc manipulation.

Böhler Welding's hybrid girth welding methodology uses the pipeRunner® bug and band system for fill and cap welding, with uphill progression using a conventional V-bevel joint preparation and rutile flux-cored wires.

			Charpy CTOD test results (J)			
Weld Area	**Position**	**Temp (°C)**	**1**	**2**	**3**	**AVG**
Root	**12 o'clock**	-30	60	60	54	58
		-60	29	41	29	33
	6 o'clock	-30	43	51	45	46
		-60	36	38	31	35
Cap	**12 o'clock**	-30	82	84	88	85
		-60	40	42	48	43
	6 o'clock	-30	80	77	84	80
		-60	43	54	52	50

Table 1: Charpy V-notch test results in a girth weld of a Grade API 5L X 70 pipe welded using the hybrid approach.

Productivity evaluation

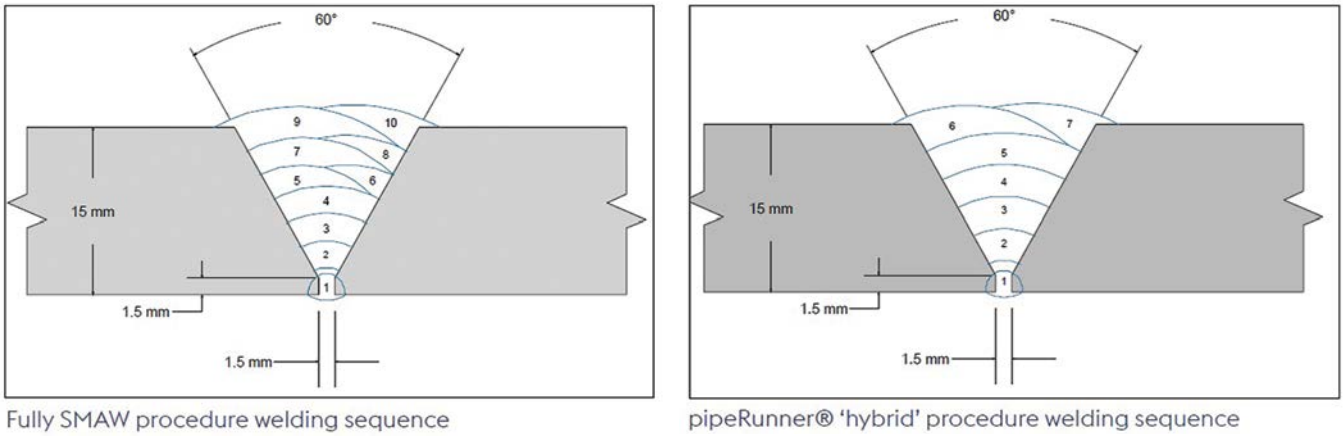
To evaluate the productivity gains, trial welds were conducted on Grade API 5L X 70 pipe with a diameter of 910 mm and a wall thickness of 15.0 mm. The trial involved the described method and a fully manual SMAW process on comparative weld joint.

The root consumable for both methods was FOX CEL (AWS A5.1: E6010), a cellulose electrode designed for vertical-down welding of pipelines. The hot pass was completed using SMAW with FOX CEL 80-P (AWS A5.5: E8010-P1).

For the mechanised fill and capping passes, the Böhler Welding pipeRunner® bug and band system with the TERRA 400 PRM welding power source and the diamondspark X70 RC-Pipe (AWS A5.29: E91T1-K2M-JH4) flux-cored wire specifically designed for pipelines were used, moving vertically up from the 6:00 o'clock to 12:00 o'clock positions. This approach resulted in a defect-free, high-quality joint with an excellent bead appearance, which was completed with five mechanised FCAW fill and cap passes in addition to the SMAW root and hot passes – seven weld passes in total. In comparison, the manual root, fill and cap passes with FOX CEL and FOX CEL 80-P required a total

Tensile test	**Result**
Yield strength (MPa)	537
Tensile strength (MPa)	613
Elongation (%)	27,8

Table 2: ASTM E8 Tensile Test results from a longitudinal sample taken at 3 o'clock.



Fully SMAW procedure welding sequence

pipeRunner® 'hybrid' procedure welding sequence

A comparison between the fill sequences for a pipe girth welding trial: Left: Pipe welded using a fully manual SMAW process. Right: Welded using a hybrid process with the fill and cap passes completed using the pipeRunner® bug and band systems with a rutile flux-cored wire.

of ten passes – three additional layers of weld deposit compared with the hybrid process.

As indicated in the tables on page 19, compared to the joint completed using the full cellulosic SMAW procedure, the use of pipeRunner® with the diamondspark flux-cored wire led to a 51% reduction in arc time and a 66% reduction in total welding time, including fit-up.

Additionally, there was a 46% net saving in terms of the mass of the consumables deposited. It is noteworthy that larger diameter or heavier wall thickness can result in further savings, as well as the utilisation of multiple welding stations, each dedicated to executing one or a few passes.

Welding of clad 625 X 65 and stainless steel Grade 1.4301 (304L) pipe

Excellent pipe welding results were also achieved on a Clad 625 API 5L X65 pipe using the UTP 2.4 mm A 6222Mo-3 TIG rod for the root and the hot pass, followed by mechanised gas shielded flux cored welding using a pipeRunner with a 1.2 mm FOXcore 625-T1 wire for the fill and cap layers.

Stainless-steel pipe girth weld using Grade 1.4301 (304L) was also successfully completed using the hybrid welding process. In this case, the 304L pipe was welded with the 2.4 mm Thermanit JE-308 L TIG rod consumable for the root and the hot pass, followed by the pipeRunner welding with the FOXcore 308L-T1 cored wire for the fill and cap layers.

When used for hybrid welding, the combination of the pipeRunner® and the FOXcore range of high-alloyed flux-cored wires offers excellent weld bead appearance with a significant reduction in post weld cleaning and a substantial improvement in productivity compared to fully manual pipeline welding for fill and cap layer.

Weld bead appearance for the fill (left) and cap (right) passes completed using vaBW's pipeRunner® bug and band mechanised welding solution.

Conclusion

In conclusion, the hybrid approach, in terms of productivity, is higher than standard stick electrodes, even cellulosic ones, while it is lower than full mechanised welding. However, there are advantages in terms of equipment cost, simplicity, and operator ease, making it a viable and attractive option for onshore pipeline welding.

The specific design of voestalpine Böhler welding flux-cored wires is able to meet critical project specifications, even when projects require good toughness properties (CTODs). The hybrid procedure is capable of providing solutions for clad pipes and other materials where flux-cored wires might be used.

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