WELDING TECHNIQUES FOR PIPELINE MECHANIZED WELDING

BY LAURENT BAUDOUIN AND FRANCESCO CICCOMASCOLO

Welding operations for onshore pipelines primarily focus on girth welds, specifically joining pipe-to-pipe. The predominant material for these pipes is often unalloyed and low-alloyed steels, and in such cases, Shielded Metal Arc Welding (SMAW) employing cellulosic electrodes remains a prevalent choice.

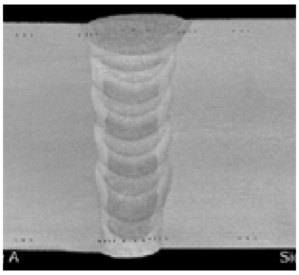
While Gas Metal Arc Welding (GMAW) mechanization are already well-established in this domain, characterized by a sophisticated approach involving narrow bevels through on-site beveling machines, internal line-up clamps, and advanced bug and band system, there is a growing consideration for a 'hybrid' 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).

HYBRID METHODOLOGY OF ORBITAL PIPELINE WELDING

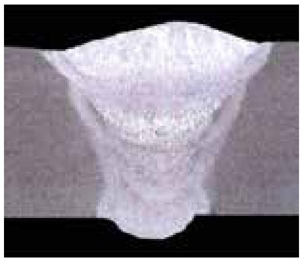
In this hybrid methodology, filling and cap welding are executed in the uphill progression using conventional V bevels. The root and the hot (2^{nd}) pass are initially performed through SMAW, and in some specific cases, Gas Tungsten Arc Welding (GTAW) or Gas Metal Arc Welding (GMAW) may be employed. This hybrid approach offers several advantages in comparison to the downhill welding technology described earlier, which typically uses solid wires in 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 on productivity, providing efficient and effective welding solutions.

This 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 optimizes the welding process in terms of performance, versatility, and operational simplicity.



Macro section: GMAW automatic orbital welding in narrow gap downhill



Macro section: Hydrid' technology in V bevel R-H SMAW, F-C FCAW in uphill progression

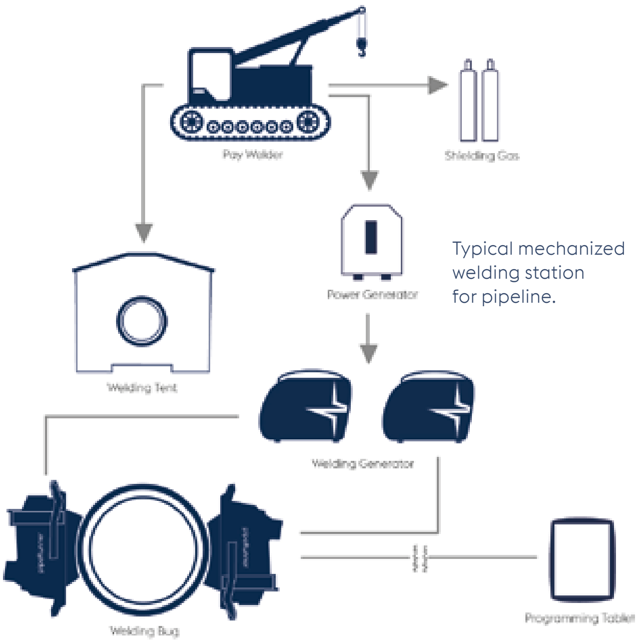
However, there are certain drawbacks to the hybrid approach:

- **Slower Process:**
  Despite a substantial deposition rate per pass, the hybrid process tends to be slower than the downhill procedure, which impacts overall welding efficiency.
- **Limitation on Double Torch Equipment:**
  The presence of slag impedes the use of double torch equipment, which sometimes is used in narrow gap (bevel) with solid wires to further improve the productivity.
- **Lower Mechanical Properties:**
  Mechanical properties, especially weld metal toughness, may be lower due to higher heat input. Fine-tuning of welding consumables, such as Böhler Welding's specialized flux-cored wires for pipelines (diamondspark X.. RC-pipe), is necessary to mitigate these effects.
- **Higher Filler Metal Consumption:**
  The necessity to fill a V-bevel instead of a narrow bevel results in higher filler metal consumption, affecting cost considerations.

On the positive side, the hybrid approach offers several advantages:

- **Lower Equipment Investment:**
  The hybrid method requires less investment in equipment compared to the complex downhill procedure.
- **Elimination of Site Beveling Machine and Internal Clamp:**
  The need for a site beveling machine and internal clamp is obviated, streamlining the welding setup.
- **Simplified bug and band System:**
  A single set of welding parameters and a simpler, less expensive bug and band system contribute to operational ease.
- **Operator-Friendly:**
  The hybrid approach is designed to be more operator-friendly, reducing the complexity of the welding process.
- **Reduced NDT Indications:**
  The hybrid process is less sensitive to lack of fusion and porosity compared to the downhill process, resulting in fewer or even no indications during Non-Destructive Testing (NDT).

In summary, while the hybrid approach introduces certain challenges, its advantages in terms of equipment cost, simplicity, and operator ease make it a viable and attractive option for onshore pipeline welding, especially when considering trade-offs in deposition rates and mechanical properties.



Typical mechanized welding station for pipeline.

COMPARISON WITH THE SHIELDED METAL ARC WELDING (SMAW) PROCESS

The described solution presents several advantages:

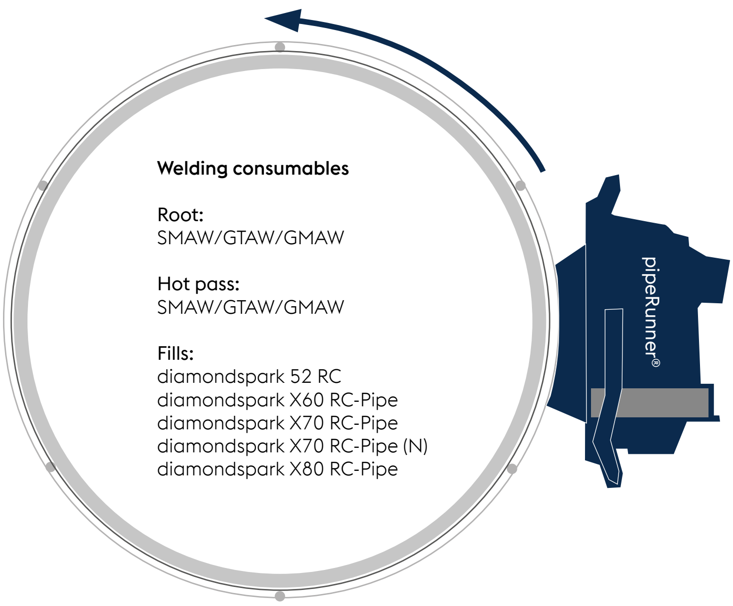
» **Improved Productivity:**
Achieves high travel speed and deposition rate, enhancing overall productivity in the welding process.

» **Reduced Downtime:**
Minimizes downtime due to the execution of programmed parameters and the absence of manual intervention, ensuring continuous workflow.

» **High Quality and Repeatability:**
Ensures high-quality welds with consistent repeatability, facilitated by the execution of programmed parameters, contributing to the reliability of the welding process.

» **Low Repairing Rate:**
Minimizes porosities and lack of fusion, leading to a low repairing rate and reducing the need for post-weld repairs.

To fully realize the potential benefits, it is imperative to utilize flux-cored wires specifically designed for pipeline applications, providing proper support to the weld bead, especially in critical positions (e.g., from 6:00 to 4:00 o'clock). An essential component of this solution is a bug and band system that is fully programmed, digitally controlled, and offers high precision in movements.



'hybrid' pipeline welding technology for un-alloyed and low-alloyed steel pipelines and pipeworks as proposed by Böhler Welding.

PRODUCTIVITY EVALUATION

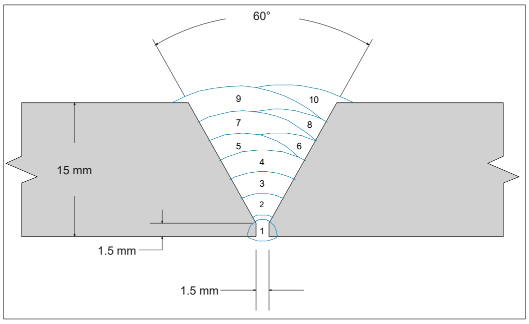
To evaluate the productivity gains, trial welds were conducted on Grade API 5L X 70 pipe with a diameter of 910 mm and a wall thickness of 15.0 mm. The trial involved the described method and a fully manual SMAW process on another weld joint.

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 mechanized fill and capping passes, the Böhler Welding pipeRunner® bug and band system with the welding power source TERRA 400 PRM 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.

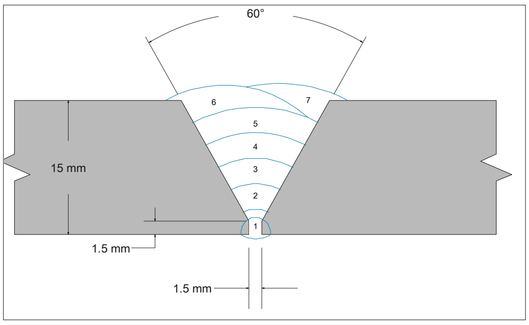
This approach resulted in a defect-free, high-quality joint with an excellent bead appearance completed in five layers. In comparison, the manual fill and cap passes with FOX CEL 80-P required depositing two additional layers.

As indicated in the tables below, 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 utilization of multiple welding stations, each dedicated to executing one or a few passes.



Fully SMAW procedure welding sequence



pipeRunner® 'hybrid' procedure welding sequence

pipeRunner® in operation


Fill layer

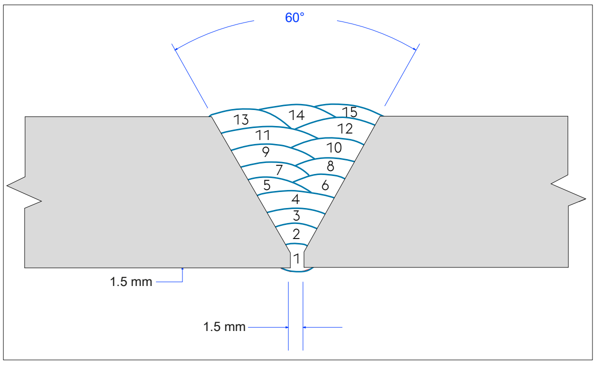

Cap layer

TEST RESULTS

Mechanical properties achieved in a girth weld using the hybrid approach. Preferable to not mention the comparison as we say that the hybrid approach basically allow to avoid the bevelling machine.

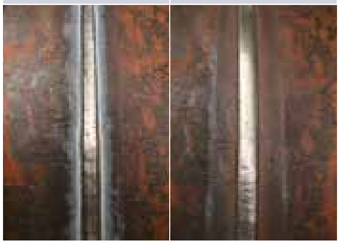
	Pipe	OD	WT	ROOT / HOT			FILL / CAP		
	Grade	**inches**	**mm**	**Process**	**Consumable**	**Gas**	**Process**	**Consumable**	**Gas**
Weld 1	X60	24"	25.0	SMAW	FOX CEL Ø 4,0 mm FOX CEL 80-P Ø 4,0 mm	N. A	m-GSFCAW	DS X60 RC-Pipe Ø 1.2 mm	M21

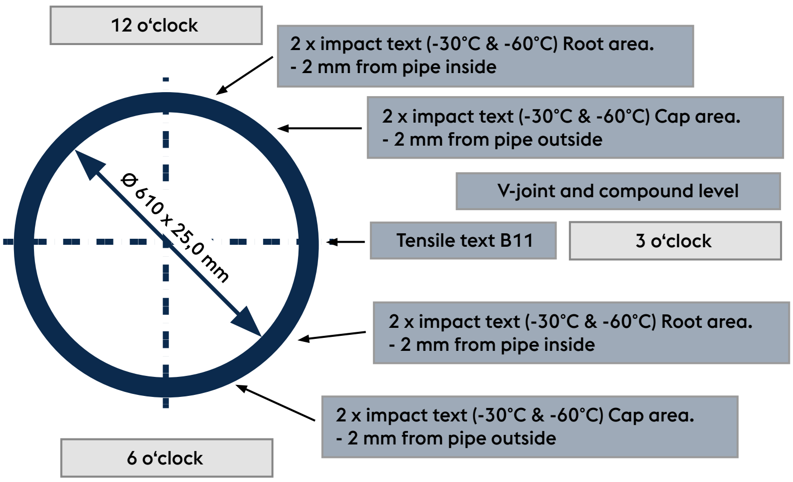
Bevel Sequence



Cut Sheets & weld bead appearance

Weld bead Appearance	
Fill Pass	**Cap Pass**





Impact test acc. ASTM E23

Charpy V notch results

			V - bevel			
Weld Area	**Position**	**Temp °C**	**1 (J)**	**2 (J)**	**3 (J)**	**AVG (J)**
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**

Tensile Results

Longitudinally 3 O'clock ASTM E8	V- joint
Yield strength [MPa]	537
Tensile strength [MPa]	613
Elongation [% Lo=4d]	27,8

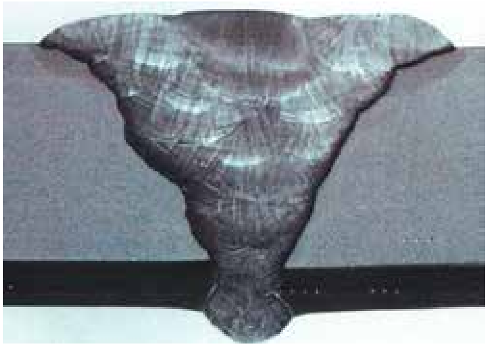
HYBRID APPROACH ALSO FOR HIGH ALLOYED AND CLAD PIPELINE

Welding of Clad 625 X 65 Pipes

Perfect weld results welding a Clad 625 API 5L X 65 pipe grade with our UTP A 6222Mo-3 Tig rod in dia. 2.4 mm for the root and the hot pass followed by m-GSFCAW mechanized gas shielded flux cored wires FOXcore 625-T1 in 1.2 mm for fill and cap layer welded with our pipeRunner®.

	Pipe	OD	WT	ROOT / HOT			FILL / CAP		
Bevel	**Grade**	**inches**	**mm**	**Process**	**Consumable**	**Gas**	**Process**	**Consumable**	**Gas**
Plate	Clad 625 X65	< 20"	20 - 25	GTAW	UTP A 6222Mo-3 Ø 2.4 mm	I1	m-GSFCAW	FOXcore 625-T1 Ø 1.2 mm	M21

Weld bead Appearance	
Fill Pass	**Cap Pass**

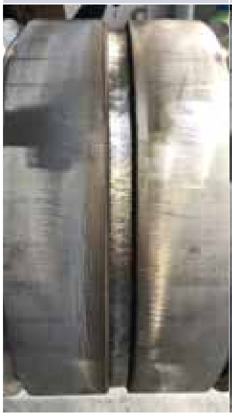
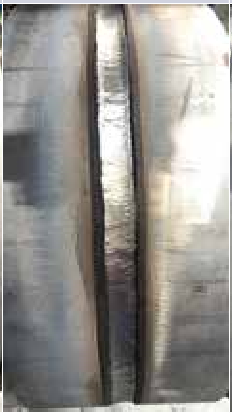
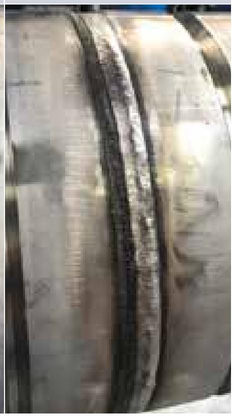


Welding Conditions	
Polarity	DC +
Welding Position	5G Up
CTWD [mm]	10 - 15
Welding Current [A]	150 – 180

Welding Conditions	
Arc Voltage [V]	23 - 26
Travel Speed [cm/min]	18 - 24
Preheating temp. [°C]	80
Interpass temp. [°C]	150

Welding of stainless-steel pipe grade 1.4301 (304L)

The Perfect Weld seam can also be reached with our stainless-steel girth weld solution. In this case welding a 1.4301 (304L) pipe with Thermanit JE-308 L TIG rod in 2.4 mm for the root and the hot pass followed by FOXcore 308L-T1 for fill and cap layer welded with the pipeRunner®

Weld bead Appearance			
1st Fill Pass	2nd Fill Pass	1st Cap Pass	2nd Cap Pass
			

Welding Conditions	
Polarity	DC +
Welding Position	5G Up
CTWD [mm]	10 - 15
Welding Current [A]	150 – 180
Arc Voltage [V]	18 - 22
Travel Speed [cm/min]	20 - 24
Preheating temp. [°C]	50
Interpass temp. [°C]	150

Boost your productivity with our pipeRunner® together with the excellent FOXcore range of high alloyed flux cored wires with significant reduction in post weld cleaning and a substantial improvement in productivity compared to fully manual pipeline welding of fill and cap layer.

CAUSES OF WELDING DEFECTS AND PROBLEM SOLVING

Trouble shooting for seamless FCAW.

By adhering to these handling instructions and implementing troubleshooting measures, welding operators can effectively manage and overcome potential challenges related to feeding issues, porosity, slag inclusions, or lack of fusion when working with seamless flux cored wires. Regular monitoring, adjustments, and adherence to recommended procedures contribute to achieving high-quality welds.

1. HOW TO AVOID FEEDING ISSUES

When encountering feeding issues in the welding process, it is crucial to systematically check the following key elements:

» **Feeding Liner Contamination:**
Ensure that the feeding liners are free of any contamination. Contaminated liners can impede the smooth feeding of the wire. Regular checks and cleaning of liners are necessary to prevent issues.

» **Damaged Contact Tips:**
Regularly inspect the contact tips for any signs of damage. Damaged contact tips can contribute to feeding problems and should be replaced at scheduled intervals to maintain optimal performance.

» **Selection of Appropriate Feeding Rollers:**
Use the correct feeding rollers that are suitable for seamless cored wires. Using the wrong type of rollers or applying too much pressure can lead to wire deformation, causing feeding problems. Ensure proper tension and alignment of the feeding rollers.

» **Wire Deformation due to High Pressure:**
Be cautious about applying excessive pressure, as it can deform the wire and result in feeding issues. Adjust the pressure settings to the recommended levels for the specific welding application.

» **Hose Bending:**
Check the hose for any excessive bending or kinking. An improperly bent hose can impede the smooth movement of the wire, leading to feeding problems. Ensure that the hose is appropriately routed to avoid sharp bends.

» **Wire Feeder Brake Adjustment:**
Examine the wire feeder brake settings. If the brake is fixed too tightly, it can restrict the movement of the wire, causing feeding issues. Adjust the brake to the recommended settings for the specific wire being used.

By following these systematic checks and taking the recommended actions, welding operators can troubleshoot and resolve feeding issues effectively, ensuring a smooth and consistent welding process. Regular maintenance and adherence to proper procedures are essential for optimal welding performance. When feeding issues appear following important things should be checked.

Issue Identified	Recommended Action
Feeding liner contamination	Clean the feeding liners thoroughly with compress air and replace if necessary.
Damaged contact tips	Replace damaged contact tips with new ones.
Incorrect feeding rollers	Ensure the use of appropriate feeding rollers (only U type). Adjust pressure as needed.
Wire deformation due to high pressure	Adjust pressure settings to recommended levels.
Hose bending	Straighten the hose.
Wire feeder brake adjustment	Adjust the wire feeder brake to the recommended settings.

2. POROSITY

Porosity in welding can result from various factors, and it is essential to examine several aspects to identify the root causes.

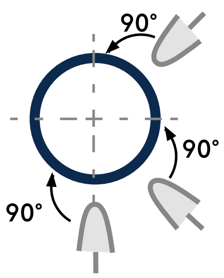
Potential Causes	Recommended Action
Improper storage of wires:	Ensure seamless cored wires are stored in a dry environment to prevent moisture absorption. Use appropriate storage methods, such as moisture-resistant packaging or containers.
Moisture pickup on wire surface:	Implement proper handling procedures to prevent exposure to moisture during storage and transportation. Store wires in a controlled environment with low humidity.
Contaminated gas nozzles:	Regularly inspect and clean gas nozzles to remove any contaminants (spatters). Replace nozzles if they are damaged or excessively soiled.
Incorrect gas flow:	Verify that the gas flow rate is within the recommended range for the specific welding application (i.e., 15-25l/min). Adjust the gas flow if it is too high or too low, following manufacturer guidelines by measuring gas flow directly on the nozzle with gas flow meter.
Weather conditions:	Be mindful of weather conditions, especially wind and rain, at the job site. Consider using windbreaks or protective covers to shield the welding area from adverse weather effects.

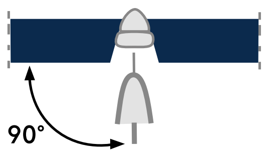
Porosity in seamless flux cored wire welding can stem from various sources, and a systematic approach is essential for troubleshooting. By addressing the potential causes outlined above and implementing the recommended solutions, welders can minimize porosity issues and ensure the production of high-quality welds. Regular equipment checks, proper storage practices, and attention to environmental conditions contribute to effective porosity prevention in welding processes.

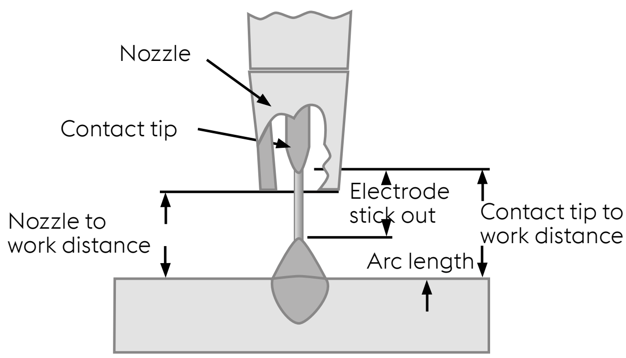
3. SLAG INCLUSIONS OR LACK OF FUSION

The occurrence of slag inclusions or lack of fusion is frequently observed on pipeline job sites when flux-cored wires are utilized. Welders, especially when introduced to flux-cored wires for the first time, may not be familiar with the proper handling procedures. In such instances, it is crucial to identify and implement the correct parameter settings for flux-cored wires to prevent issues related to lack of fusion or slag inclusion.

Potential Causes	Recommended Action
Inadequate welding parameters leading to lack of fusion	Enhance amperage and voltage settings.
Incorrect wire stick-out	Follow the recommended wire stick-out range of 15 mm – 20 mm.
Incorrect arc length » Too short arc can lead to spatters » Too long arc can lead to low penetration and lack of fusion	Adhere to the recommended arc length range of 3 mm – 5 mm.
Improper torch angle resulting in slag inclusions	Maintain a torch angle of approximately 90° in all positions.
Incorrect weaving width and travel speed settings	Adjust weaving width and travel speed to optimal parameters.







CONCLUSIONS

In conclusion, the hybrid approach, in terms of productivity, is higher than standard stick electrodes, even cellulosic ones, while it is lower than full mechanized 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 bohler welding flux-cored wires is able to meet critical project specifications, even when projects require toughness properties (CTODs). The hybrid procedure is capable of providing solutions for clad pipes and other materials where flux-cored wires might be used.

LAURENT BAUDOUIN

GLOBAL INDUSTRY KEY ACCOUNT MANAGER PIPELINE

With a rich background spanning 24 years in the welding industry, I have garnered diverse experience, dedicating nearly 17 years to various roles in pipeline welding services. My journey evolved from a field welding engineer to the position of R&D Welding Manager. Currently, I hold the position of Global Key Account Pipeline Manager, overseeing crucial accounts on a global scale.
My primary focus is to leverage my extensive pipeline welding expertise in supporting our global sales teams for this product range. I derive great satisfaction from visiting key customers, aiming to gather valuable feedback. By seamlessly integrating our unparalleled portfolio components into welding solutions and applying our unique metallurgical and application know-how, my objective is to deploy effective value-selling skills in identifying and engaging potential customers.

FRANCESCO CICCOMASCOLO

HEAD OF FULL WELDING SOLUTIONS

I have been working in voestalpine Böhler Welding since 2012, after several years spent in the welding industry in various roles, as design engineer, QA/QC manager, welding coordinator and field service manager.

In my actual role I am managing projects which combine welding equipment, automation, consumables and accessories to develop turn-key solutions adding value through know-how in metallurgy and applications.

Dealing with different types of mechanization and automation in welding is part of my working life in the last two decades; the related competence gained over the years is highly beneficial in my current activities.

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