SUCCESS CASES OF ACCELERATED WELDING PRODUCTIVITY THROUGH AUTOMATION

BY FRANCESCO CICCOMASCOLO

INTRODUCTION

Rising the productivity at the highest level, in combination with high quality and flexibility, is one of the modern times biggest challenges for the welding industry.

Driving force is the hard competition together with the increasingly lack of skills and competence that affects this industrial sector.

It is also to be considered that best productivity does not only mean the highest welding speed, but also fast set-up, low downtimes and high reliability.

Based on the needs the welding equipment providers make nowadays available several automated and mechanized solutions to cover any demand such as welding carriages, orbital bugs and several types of robotic systems.

In this paper 4 GMAW applications cases are illustrated showing concrete benefits achieved in the fabrication of LNG tanks, pipeline, steel structures and Yellow & Green goods, thanks to mechanized and automated solutions and the right welding consumables. Saving in terms of time and also material, when applicable, are also illustrated.

WELDING OF LNG TANKS – BUTT WELDS IN VERTICAL POSITION

Welding of 9 % Ni steel LNG tanks on site is mainly about butt welds in vertical-up or frontal position. The welding consumable are Nickel alloy type for metallurgical reasons and these welds are often performed using SMAW.

Such a conventional welding technology brings clear limitations due to the following issues:

- Frequent interruption to exchange the stick electrodes and for slag removal
- Material waste and consequently high cost of the welding consumables
- Skilled manual welders are necessary
- Perfect repeatability and fulfillment of the established WPS not always ensured

To reduce these issues, GMAW and FCAW semi-automatic solutions have been adopted during these years, bringing a significant improvement in all the mentioned aspects.

Flux cored wires, featuring a fast – freezing slag system supporting the welding pool, resulted to be the most efficient welding consumable for such positional welds.

The usage of welding carriages, running over rail tracks both semi-rigid and flexible type, in combination with flux cored wires realized a further enhancement reaching the benefits given below:

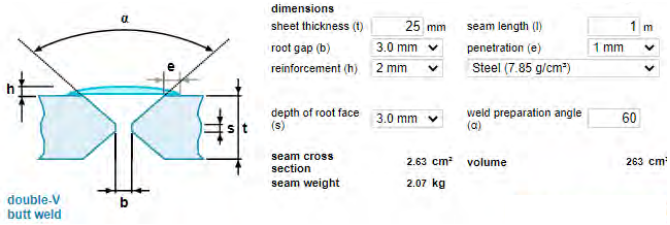
- **Higher Production Efficiency**
  - Depositions rates as high as 85 % - 90 % (5 - 8 x that of SMAW)
  - No electrode wastage
- **Higher Weld Quality**
  - Greatly reduced stops and starts
  - Minimize critical weld failures and rework
  - Eliminate grinding or weld cut outs
- **Less Skill Required**
  - Mechanized equipment maintains precise control of welding parameters
  - Lower skill ceiling required to produce high quality welds

Modelling time and material efficiency for a typical butt weld of a 9 % Ni steel LNG tank with SMAW, one may realistically consider a process duty cycle (arc-on time vs. total time) of about 20 % on 1.5 kg/hr deposition rate and material loss of about 30 % (or even more).

Based on that assumption, for e.g. a typical case, i.e. 25 mm plates with X preparation, calculations lead to a total manufacturing time of 468 min. using 3.34 kg of welding consumables for 1 m length, as reported in the table below.

In the case of the Böhler Welding mechanized solution, the process duty cycle can raise up to 80 % (longitudinal non-interrupted welds) with a deposition rate of 3.4 kg/hr and a material efficiency above 90 %. That brings to a very interesting scenario, where the time to completion is 49 min. only (vs. 468 min. by SMAW), so 9 - 10 times less and material usage 2.6 kg (more than 20 % less). The below tables give details on assumptions and calculations done, also for the FCAW semi-automatic with results positioned in between.

Input data and outcome results according to the Böhler Welding calculation software tool



1 meter length plates welding	
Thickness 25mm	Preparation X – 60°
weld metal cm^3	263
kg	2.3

Calculation of weld metal

Process			
Process	Duty cycle	Theoretical deposition rate [kg/hr]	Effective deposition rate [kg(hr]
SMAW	20 %	1.5	0.3
FCAW semi-automatic	35 %	3.4	1.19
railRunner FCAW mechanized	85 %	3.4	2.89

Process efficiency

Calculation			
Process	Welding time [min]	Kilogram used	Efficiency
SMAW	468	3.34	70 %
FCAW semi-automatic	118	2.60	90 %
railRunner FCAW mechanized	49	2.60	90 %

Welding times and filler metals consumption

More in details, the Böhler Welding mechanized solution uses alloy 625 flux cored wire FOXCore 625-T1 (AWS A5.34: ENiCrMo3T1-4) d. 1.2 mm with the new track mounted welding carriage railRunner in combination with a heavy-duty cycle welding equipment TERRA 400 or 500 PME.

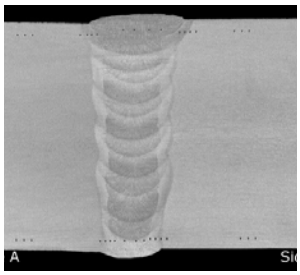
Additionally, FOXCore 625-T1 together with the Böhler Arc welding program, gives an excellent bead shape with self-detaching slag and weld metal free from porosity.

ORBITAL GIRTH WELDS OF PIPELINE

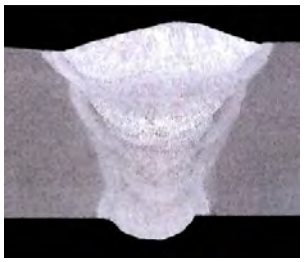
On-shore pipelines welding is a typical site operation. It is all about the girth welds pipe-to-pipe. The wide majority of laid pipes are in un-alloyed and low-alloyed steels; in that case, SMAW with cellulosic electrodes is often still used.

GMAW automation and mechanization is anyhow already quite present in this field normally with a relatively complex approach, which brings in the picture narrow bevels with site beveling machines, internal line-up clamps, and highly sophisticated orbital systems along with refined fast-speed welding procedures using solid wires in downhill.

A third possible solution, which we can call 'hybrid' is an optimal compromise among flexibility, easiness of use and productivity. It is based on orbital systems and rutile FCWs. Fills and cap welding are performed in uphill with this technology in the conventional V bevel, after the root and hot (2nd) pass executed by SMAW (or even GTAW/GMAW in some specific cases). It brings the following benefits, compared with the downhill technology above described.



Macro section: GMAW automatic orbital welding in narrow gap downhill

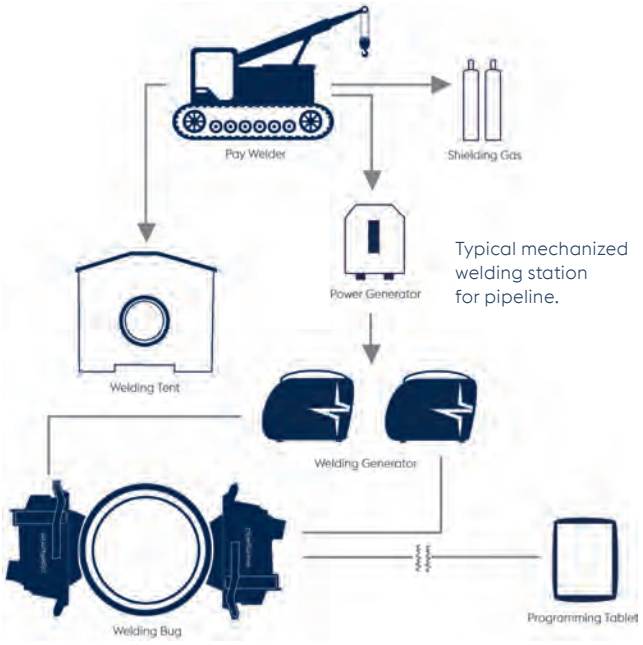


Macro section: Hybrid' technology in V bevel R-H SMAW, F-C FCAW in uphill progression

On the other hand, the disadvantages are the following:

- In spite of the big deposition rate of each pass, process is slower than the downhill procedure.
- Double torch equipment cannot be used for the presence of the slag
- Mech. Properties are usually lower than downhill procedure due mainly to the higher heat input. Especially weld metal toughness could be affected hence, the welding consumables must be fine-tuned for the application. In these circumstances, Böhler Welding designed flux cored wires for pipeline, called diamondspark X.. RC-pipe.
- Filler metal consumption is higher because a V-bevel must be filled, instead of a narrow bevel.

- **Less investment in equipment**
  - Site bevelling machine is not necessary
  - Internal clamp is not necessary
  - Only one set of welding parameters i.e. simple and less expensive orbital system
- **Easier for the welding operators**
- **Less NDT indications. Less sensitive to lack of fusion and porosity than downhill process**



Typical mechanized welding station for pipeline.

In comparison with the SMAW process this solution offers the following advantages:

- Improved productivity – high travel speed and high deposition rate
- Reduced downtime
- High quality and repeatability thanks to the execution of programmed parameters and no manual intervention
- Low repairing rate minimizing porosities and lack of fusion

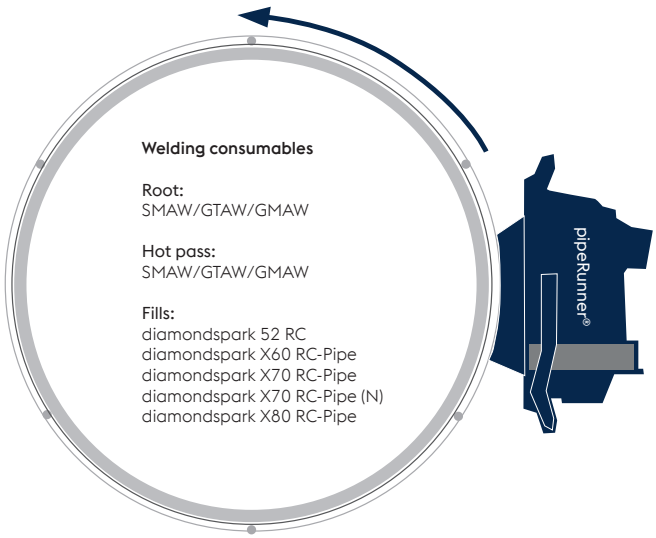
It is crucial to use flux cored wires designed for pipeline application to support properly the weld bead especially in the critical position, i.e., from 6:00 to 4:00 o'clock and an orbital system fully programmed, digitally controlled, offering high precision in movements.

In order to evaluate the gain in terms of productivity, Bohler Welding executed trial welds on Grade API 5L X 70 pipe with a diameter of 910 mm and a wall thickness of 15.0 mm have been performed using the above-mentioned method and the fully manual SMAW process on another weld joint.

For both, the root consumable used was the FOX CEL (AWS A5.1: E6010), Böhler Welding's cellulose electrode designed for vertical-down welding of pipelines. The hot pass was completed using SMAW, using the FOX CEL 80-P (AWS A5.5: E8010-P1).

For the mechanized fill and capping passes, the Böhler Welding pipeRunner® orbital system with welding power source TERRA 400 PRM and the diamonspark X70 RC-Pipe (AWS A5.29: E91T1-K2M-JH4) flux cored wire specifically designed for pipeline were used moving vertically up from the 6:00 o'clock to 12:00 o'clock positions.

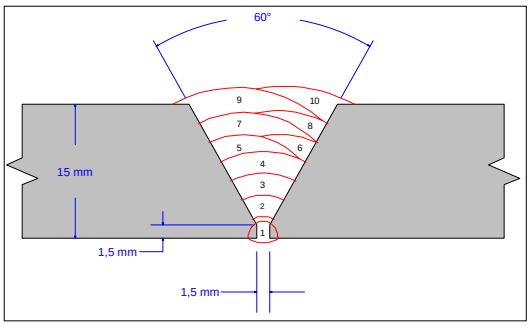
This procedure enabled a defect-free, high-quality joint with an excellent bead appearance completed in five layers. For the manual fill and cap passes FOX CEL 80-P was used, depositing 2 layers more.



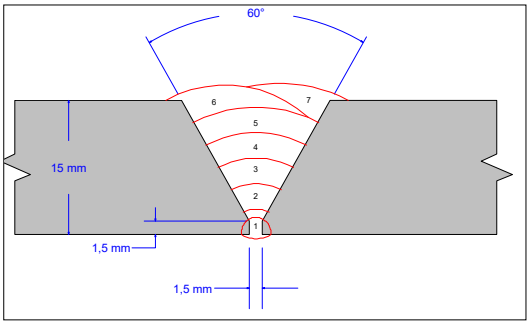
'hybrid' pipeline welding technology for un-alloyed and low-alloyed steel pipelines and pipeworks as proposed by Böhler Welding.

As per the tables below, compared to the joint completed using the full cellulosic SMAW procedure, the use of pipeRunner® with the diamondspark flux-cored wire reduced arc time by 51 % and total welding time, including fit-up, by 66 %, while net savings in terms of the mass of the consumables deposited amounted to 46 %. To be remarked that biggest size diameter or heavier wall thickness will bring further savings, as well as the usage of multiple welding stations, each one dedicated to the execution of one or few passes.

Arc Times and total times	Fully SMAW	Ø 4.0 / 5.0 mm	Arc time: 71 min 42 sec Total time incl. line-up, electrode change 10 sec. each, slag grinding 60 sec. each pass: 109 mi.
	R-H SMAW F-C pipeRunner® with diamondspark X70 RC-Pipe	Ø 4.0 / 5.0 mm Ø 1.2 mm	48 min 25 sec Incl. Line-up, repositioning of pipeRunner®: 30 sec. each pass: 66 min
	› Arc Time saving 51 % with the pipeRunner® solution › Total Time saving 66 % with diamondspark X60 RC-Pipe		
Electrode-Wire consumption	FOX CEL / FOX CEL 80-P	Ø 4.0 / 5.0 mm	3.7 kg
	FOX CEL/ FOX CEL 80-P diamondspark X60 RC Pipe	Ø 4.0/1.2 mm	0.32 kg + 1.7 kg
	› 46 % less filler metal consumption with the pipeRunner® solution		



Fully SMAW procedure welding sequence



pipeRunner® 'hybrid' procedure welding sequence

pipeRunner® in operation

Fill layer

Cap layer

SERIAL PRODUCTION OF COMPONENTS USING COLLABORATIVE ROBOTICS

For components in small series and flexible production often welding shops are not attracted by industrial robotic solutions because they are not enough versatile. Running a robotic welding cell requires a lot of concepts, installation topics and fine-tuning programming which are affordable and profitable mostly for high-scale productions.

The result is that these companies continue to weld with GMAW semi-automatic (manual) facing all the issues due to the welder skills, the relatively low duty cycle related to the human factor, the un-constant quality for the same reason.

To meet the increasingly demand in this industrial sector, the new tendency is offering working stations based on collaborative robotics. Collaborative robots are applied in manufacturing since years but only recently they joined the welding world.

The main difference with the conventional robots is the interaction with operators in the working area; in fact, due to the lighter weight and slower arm movement, the operator can access the working area during operations, directly move the arm to make welding programs acquiring points, make position adjustment etc.

Consequently the solution is also “plug and play” and easy to move so it can occupy different locations in the shop according to the task which it is going to perform, while industrial robots are installed in a fixed position.

A collaborative robotic welding installation

In comparison, start-up operations (programming, masking, training etc.) are dramatically simplified and the software interface is accessible and understandable also for welders and operators with basic knowledge.

The inherent limitation of lightweight and slower movements is the shorter length of the arm, which reduce the working area to about 2 m^2. This is anyhow sufficient for a wide variety of industrial components, such as machine leverages, small tanks and vessels, pre-fabrications, accessories, brackets and supports.

Of course, when the part to be welded is massive, higher specialization is necessary, or the aim is to maximize the productivity in large series, more complex manipulation and more specific solutions are requested, leading back to industrial robotics systems, which are more efficient in those cases.

As an example of a typical and successful collaborative robot user, company Bozonet located in France, in the region Bourgogne Franche Comté provides turn-key manufacturing solutions covering the whole design, concept fabrication and delivery, dealing with vessels and various type of structures and parts, including laser cutting and welding operations. Bozonet fabrication handles more than 100 different types of small and medium size parts.

Bozonet, implemented the collaborative robotic solution by Böhler Welding CO-BRO® with a welding equipment Uranos NX 3200 GSM in its manufacturing facility. As a result, after few hours of programming and using the Böhler Welding PulseDrive pulsed arc welding process, Bozonet was able to increase brackets productivity from 250 to 400 pieces/day with high quality and reliability.

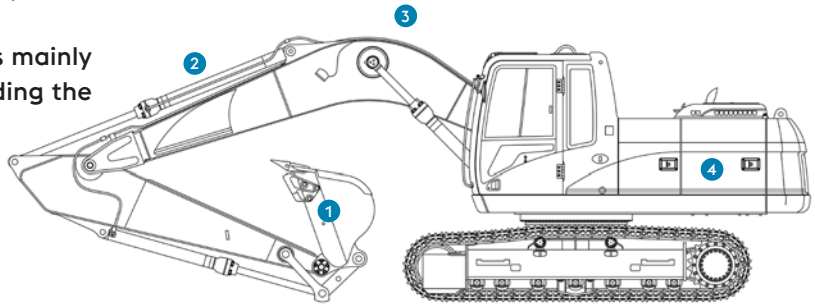
Bracket serial production using CO-BRO® at Bozonet

HEAVY DUTY ROBOTIC FILLET WELD IN THE YELLOW & GREEN GOOD INDUSTRY

The Yellow & Green good industry includes the fabrication of earth moving, crane & lifting and agricultural machines. Regarding the earth moving, excavators, graders, rollers are the typical machinery. In agriculture, reference is made to harvesters, forestry equipment, lawn equipment.

Taking an excavator as an example, it involves mainly the construction of the following items, regarding the welding aspects:

- Bucket and bucket ear (1)
- Hydraulic cylinders (2)
- Arm and boom (3)
- Frames (X-frame, main frame, crawler frame) (4)



An excavator and its components. A typical Yellow Good.

Especially the first 3 components are made of large dimension parts in mostly mild steel with wall thicknesses up to 30 mm and more. Fabrication involves lap welds, butt welds and above all fillet welds. Fillet welds are mostly in single pass, but also multi-pass joints are present, depending upon the required throat dimension. Long seams and long welding time are often necessary.

Source MTS srl

As one can easy guess these applications makes large use of robotic welding cells including even complex types (e.g., 2 robots for a large excavator frame) and using sometimes high deposit multi arc MAG processes.
Most of the time these installations are equipped with positioners that allow the part to be placed in the most favorable position.

Fabricator requirements are basically the following:

- Maximum productivity (high deposition rate)
- High reliability of the process even with variable air gap due to assembly clearance in large structures
- A minimum of installation downtime (change wire, wear parts)
- High quality of the weld for the construction integrity
  - Right mechanical properties
  - Right penetration, no undercuts and other welding defect which may result in structures failure in service
  - Right dimension and right geometry
- High quality of the weld for aesthetics and correct material utilization:
  - Perfect bead shape, especially when visible
  - Again, right dimensions and right geometry.
- Minimum of postweld and interpass cleaning operations due to spattering or silica islands

To fulfill all the above-mentioned requirement, several tailor-made applications have been developed in this field thanks to the dedicated filler metals and the right know-how regarding welding technology and metallurgy.

The below picture shows a good example of a heavy-duty robotized fillet weld application on 10 mm mild steel plates for a frame of an earth-moving machinery. Requirements from the design dpt. were a throat dimension of at least 6 mm, possibly in single pass with a good bead aspect and no welding defects, hence right penetration and no undercuts
The mentioned weld was performed using the non-coppered solid wire ECOspark® 460 d. 1.2 mm (AWS A5.18: ER 70S-6) and the special welding process QuickPulse. Robotic welding power source used was URANOS NX 5000 PSR. Perfect arc performance was achieved applying the Böhler Arc synergic program.

The ECOspark wire is characterized by a good arc stability also at high amperage, while the process QuickPulse increases travel speed and penetration as well as features a narrower arc, easier to control. The combination allows to increase the wire speed and consequently the deposition rate, still keeping a good bead aspect.

In this case, a perfect fillet weld without undercut and a very flat and symmetric profile was obtained. The throat dimension a was 7 mm with high penetration in one single pass. Deposition rate was 8 kg/h, resulting in + 30% productivity in comparison with conventional spray-mode and coppered wires, without the need of sophisticated hardware, like multiple wires systems.

To be remarked that robotics is the perfect playground for this application because of the high welding parameters as well as the introduction of a slight weaving to improve the weld profile.

Robotic fillet weld high productivity using non-coppered wire ECOSPARK 420 and process QuickPulse.
Pictures shows the perfect bead profile without undercuts, good penetration, no spattering and very few residuals such as silica islands on the weld.

- Welding parameters:
- Wire feed speed: 15,1 m/min (deposition rate: 8 kg/h)
- Amperage: 420 A
- Voltage: 37 V
- Welding speed: 40 cm/min
- Oscillation Width: 4mm
- Oscillation frequency: 1Hz

- Bead measurements
- 10x10 mm fillet weld
- Throat dimension a= 6,8mm
- Including penetration s= 12 mm

THE BÖHLER WELDING AUTOMATION PRODUCT RANGE

The present paper presented cases where automation from Böhler Welding has been successfully used. Below a short summary of the available solutions are given.

wheelRunner and railRunner

wheelRunner and railRunner are flexible and versatile welding carriages, respectively wheeled and on track, to cover all the possible heavy-duty long seams applications. Frames, beams, tanks, shipyard components, can be profitably welded using this equipment, both on-site and in-shop.

Key features are:

- Fastset-up – easier installation and positioning. Moreover, these carriages simply hold manual welding torches.
- The user single interface concept – welding process and movement are on a single control panel
- Safety at the working place – high voltage power-feed is away from the working place without need of batteries

pipe Runner® FCAW orbital system

The pipeRunner® in combination with Böhler Welding flux cored wires is the solution for pipeline and piping welding achieving perfect girth welds with excellent material properties and highest quality, minimizing NDT indications and repairing rate. pipeRunner® is characterized by the highest precision in movement as it is digitally controlled and all parameters are programmed. Positioning on the bands is easy, set-up and maintenance are intuitive. The pipeRunner® is also featuring light weight and optimized ergonomics.

pipeRunner®

railRunner

wheelRunner

CO-BRO® GUARD

CO-BRO®

CO-BRO®

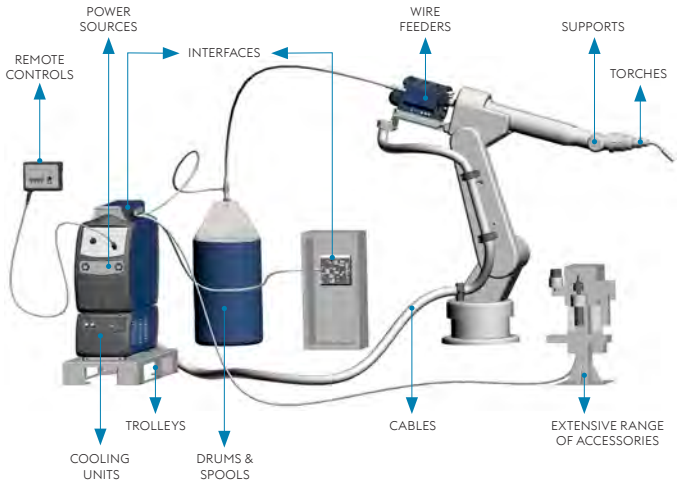
CO-BRO® is state of the art regarding collaborative robotic system for welding. All installation and start-up operations (programming, masking, training...) are very simple and at the same time ensure, the maximum flexibility, thanks to the dedicated operative welding software that allows intuitive programming suitable for all the welders or operators. The CO-BRO® portfolio actually includes 3 different solutions: CO-BRO®: the welding process and the software interface for the collaborative robot and the related working area, available for both GTAW and GMAW processes CO-BRO® FLEX: the GMAW complete plug and play solution equipped with the peripheral protection CO-BRO® GUARD: the GMAW complete plug and play solution equipped with the exclusie GUARD cabin, which ensures the maximum HSE protection and completely separates the welding from anything else in the workshop.

INDUSTRIAL ROBOTICS SOLUTIONS

Böhler Welding product range for industrial robotics

Böhler Welding offers complete ready-to-weld solutions for robotics, perfect for any set-up, combined with its top-level expertise in metallurgy and filler metals. The product portfolio is really comprehensive including all the welding components related to the welding process (power source, wire feeders, interfaces, torches, accessories, software and filler metals). Moreover, the Böhler Welding technical support is active in providing customizations of both software and hardware whenever is required.

Benefits go from the easy interfacing with the preferred robot system to perfect wire feeding in any installation layout thanks to the several options available. All components, including welding consumables, are designed to work together.



The Böhler Arc concept

Finally, also the Böhler Arc welding programs are mentioned in this paper. Böhler Arc is substantially a library of synergic programs in continuous evolution, implemented and fine-tuned based on Böhler Welding consumables. Böhler Arc ensures the best performance of the welding process when using Böhler Welding consumables, with constant high quality and repeatability. Therefore, the perfect combination of process, filler metal and welding equipment is achieved, maximizing performances and arc stability coupled with an outstanding ease of use, resulting in great advantages for the welder and efficiency for the industrial process.

CONCLUSIONS

Presenting 4 GMAW success cases in various fields, aim of this paper is to emphasize that automation and mechanization might be applied in very different industrial situations and can be declined by means of several types of machinery.

Welding carriages, orbitals systems, robotics either industrial and collaborative are mentioned in the text; it can be observed that the design and working concept heavily differ from each other, same way as welding challenges can substantially vary case by case, for customer needs, environmental conditions, specific welding conditions and parameters.

Last but not least, also the welding consumables might be fine-tuned for these automated applications in order to achieve the best results.

Selecting the right equipment and the specific welding consumables is then a key to achieve concrete benefits, but this is not all: the way how they work in synergy and the expertise offered in the various industrial challenging applications by a solution provider make the real difference.

FRANCESCO CICCOMASCOLO

GLOBAL FULL WELDING SOLUTIONS MANAGER

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.