POLYSOUDE

THE ART OF WELDING

Automated TIG weld overlay cladding

Including TIG^{er} Technology - THE Polysoude innovation

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1. Preface

TIG (Tungsten Inert Gas) welding is a recognised process that is regularly chosen and used for the industrial manufacturing of welded structures. Originally, this manual welding technique offered one of the few possibilities of joining noble materials and a few exotic alloys. The results achieved largely depended on the qualification, dexterity and experience of the welder assigned to the operation.

The excellent quality of TIG welds has resulted in the automation of the process, favoured by:

- The exceptional stability of the TIG process enabling welding parameters to be varied over a wide scale,
- The possibility of controlling the quantity of metal deposited independently of current intensity.

Mastery of the TIG progress has progressed in step with developments in electronic systems, thereby paving the way to applications in all positions. Complex welding sequences can be programmed in advance on a computer to guarantee repeatable control of all mechanical and electromechanical parameters. Depending on the environment and the typology of the weldments, it is possible to set the workpieces in motion by means of mechanical subassemblies (turntables, turning gear or positioners), or build more sophisticated machines where the torches are integrated into the welding heads rotated around the workpieces (in the case of orbital welding).

It has also been possible to put the experience gained in the fields of orbital welding and automation to use in buttering and cladding applications using the TIG process and variants of this technique or in a bi-cathode TIG^{er} configuration for high-yield depositions.

Although quite specific, cladding operations do in fact require the same fineness to achieve satisfactory results. Hence the reliability of process control, repeatability, welding capability in all positions, near-independent management of filler metal and ease with which sequences can be mechanised all help to guarantee bead quality and dilution control, and consequently the behaviour of the deposits in service.

2. **TIG cladding applications**

Cladding operations using the TIG process generate good results in the following types of application:

- repair of worn parts in service or following a manufacturing anomaly,
- preventive cladding operations for particular hazards (wear, corrosion, etc.),
- buttering operations as part of a more complex welding process for heterogeneous joints.

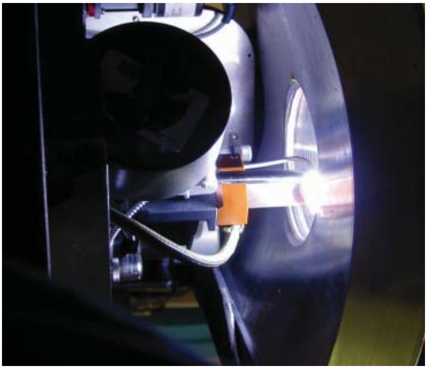
Fig. 1 : Corrosive resistant alloy valve cladding

Part repair operations - the most frequent and easiest to identify - concern homogeneous components subject to attack which simply require a machining or equivalent operation to eliminate the damaged areas (fissuring, cracking, erosion, etc.) followed by a cladding phase by redepositing materials identical to the composition of the substrate.

In the majority of cases, these operations are performed on high value-added stainless steel parts. Welding does not fundamentally change the metallurgical characteristics of the parent materials, but does increase the stress level in the repaired part.

This situation is, for example, very common for piping used in the nuclear reactor environment.

Parts scrapped as a result of machining anomalies can also be restored by welding. It is more difficult to envisage automated welding in such cases except where the geometry of the workpiece is compatible with a generic tool.



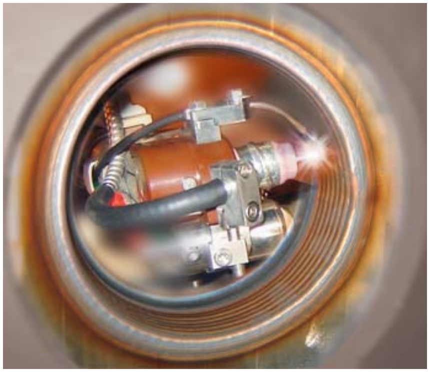


Fig. 2: Branch repair by internal cladding with 316L on a nuclear power plant primary circuit. The welding head is positioned inside the piping. An endoscope is used for remote monitoring by the operator. Welding is continuous (no stoppage on each revolution) due to the use of an orbital head with a collector.

The metallurgical approach of cladding on some parts to be repaired is sometimes complex, particularly where their material is incompatible with a welding operation, such as:

- low-alloy grades,
- Cr, Mo grades with very high carbon equivalents,
- refractory, martensitic steels that are difficult to weld without embrittlement due to the fact that it is impossible to perform heat treatment post-welding for multiple reasons.

This situation is encountered, for example, when repairing apparatus bodies, drive shafts, mechanical components, castings, etc.

The manufacturing cycle of new parts comprising coated bearing surfaces, end pieces or grooves is a conventional process. There is nothing specific about these operations other than that they are performed in a workshop with dedicated means and greater flexibility for performance (rotating parts, heat treatment, machining adjustment, etc.).

The specific case of buttering is an intermediate situation as it involves forming a deposit, not to protect the parent metal from an external hazard, but rather to create a metallurgical transition zone with the aim of making a heterogeneous joint. Unlike cladding, buttering plays an integral part in the mechanical strength of the final weld once the joint has been made. Acceptance criteria are therefore tighter due to the mechanical guarantees to be obtained. The stakes are the same during a welding operation where the use of

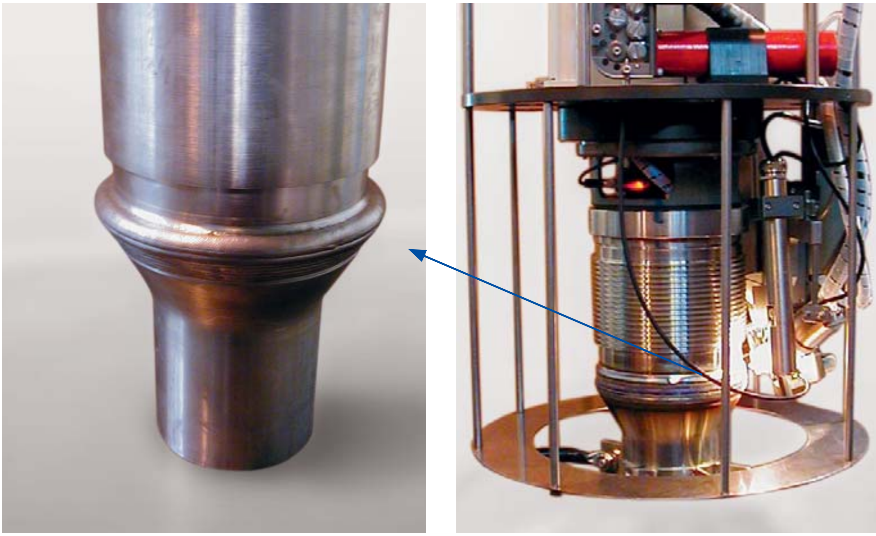


Fig. 3: Reconstitution of a canopy seal on the outside diameter of an adapter to be installed on a nuclear reactor cover head.

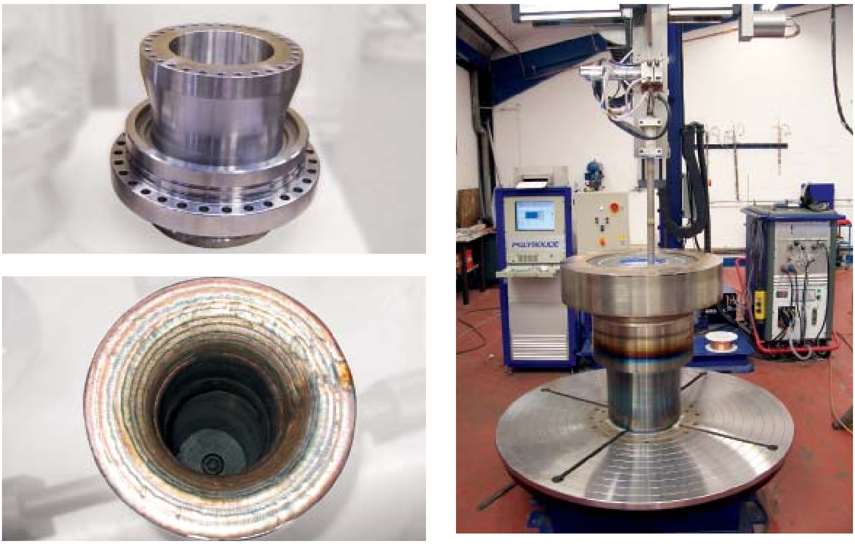


Fig. 4: Fixed welding installation for workshop production. Cladding the inside surfaces of a workpiece - wall, edge and bottom - with a nickel-based alloy.

conventional processes in line with the acceptance criteria (linked to manufacturing codes) is strongly recommended. In this manufacturing scenario, Hot Wire TIG welding is furthermore recommended in order to guarantee weldment quality.

Fig. 5: Buttering a nozzle end-piece in preparation for a heterogeneous weld.

3. Basic principles of the TIG process

3.1. TIG welding process with hot or cold wire and TIG^{er} technology

TIG welding is characterised by the creation of an electric arc between a refractory (tungsten) electrode and the workpiece in a neutral atmosphere.

The electrode withstands the high temperature of the arc and directs it towards the fusion zone. The impact of the energy causes the fusion of the parent metal which forms the weld pool shielded by the inert gas flow.

In the case of cold-wire TIG cladding, the energy required to melt the wire comes from the TIG arc, thus creating interdependence between the welding parameters to guarantee a balance between the proportion of energy designed to melt the substrate and that devoted to the filler metal.

The Hot Wire TIG process uses a current source entirely dedicated to preheating the wire by a Joule effect. This source does not provide complete autonomy for the fusion of the filler metal but does considerably limit arc energy consumption thereby providing relative independence between the deposition rate settings and the TIG arc.

In the bi-cathode configuration, two electrodes of the same polarity, at the same potential as a conventional TIG arc, are powered in parallel by direct currents. The attraction of the two arcs and the proximity of the electrodes cause the two arcs to merge into a single fused arc. In the electrode and wire orientation setup proposed by the TIG^{er} process, this high-amperage but low-pressure fused arc has shown to be particularly conducive to cladding. The same principle as for conventional TIG welding is used for the Hot Wire feed apart from the fact that only an AC source, due to its neutrality, enables control to be maintained over the wire impact point in the weld pool.

3.2. Welding current

3.2.1. Characteristics of the sources and types of current

The basic installation comprises a welding power source (with an internal cooling system for the torch), a welding torch, an inert gas source and an earth cable.

The current sources used for TIG welding have drooping or vertical characteristics for usual arc voltages of 9 to 18 V (when used with a helium shield). With this type of characteristic, the current can remain constant despite variations in arc height.

The source used for TIG welding can be direct current or alternating current (when welding aluminium).

With direct current, almost all applications require the electrode to be connected to the negative terminal of the power source (DCEN). The electrode thus behaves in a similar way to a cathode. Connecting the electrode to the positive terminal (DCEP) is possible although there are very few cases where this is used.

The current sources and polarities used in the case of TIG^{er} are identical to that used for conventional TIG welding.

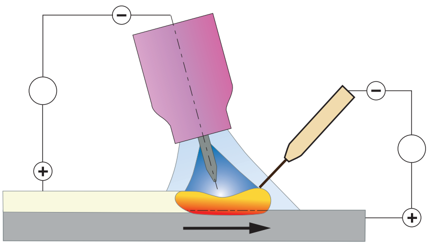


Fig. 6: Conventional configuration for monocathode Hot Wire TIG welding. The TIG electrode and wire each have a separate current source although both have negative polarity.

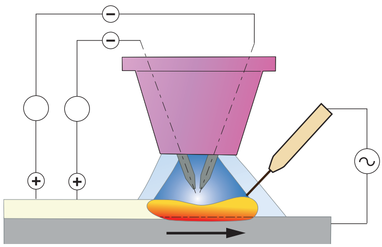


Fig. 7: Welding configuration using TIG^{er} technology. The TIG electrodes and wire each have a separate current source but the Hot Wire source is an AC source to prevent instability caused by interactions with the welding arc.

3.2.2. Pulsed welding current

As in the case of TIG and orbital TIG welding, cladding may, depending on the type of activity, require the use of direct current (constant intensity) or so-called “pulsed” current.

Direct-current welding is generally restricted to applications requiring very high efficiency in welding positions allowing the formation of very large pools (flat-position and horizontal vertical welding) sometimes using multi-head machines.

On the other hand, where the weld pool must be controlled in position, it is practically essential to resort to the use of pulsed currents (the current itself being synchronised with the wire feed and arc voltage control).

Pulsed current welding integrates the following notions:

- Alternating high and low current pulses with a frequency generally less than 6 Hz
- During the higher current state, the pulse current melts the substrate and the filler metal with maximum performance to ensure efficiency and compactness
- The lower current, known as the background current, provides cooling time to maintain control over the volume and behaviour of the weld pool, generally with regard to gravity

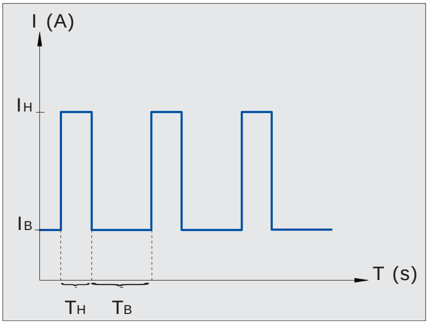


Fig. 8: Current pulsing for TIG welding

- Depending on the settings, pulsed current enables the operator to adjust the compactness, appearance and regularity of the weld beads.

Additional remarks:

▶ The link between weld pool movements during the pulse and background current times can only be used for pulses of less than 8 Hz, i.e. for values less than the natural frequency of the materials (e.g. 6 – 7 Hz for stainless steels).

▶ The effects of the pulsed current are amplified by synchronising the wire feed speed, the heating current and possible oscillation movements. In this case, the effective range of use is even narrower in terms of frequency (of the order of 0.5 to 3 pulses maximum per second).

▶ When welding medium to thick materials, it is recommended that the background current period be at least equal to the pulse current period (cooling effect), or even longer (conventional scenario: Pulse = 200 ms and Background = 300 ms or Pulse = 300 ms and Background = 500 ms).

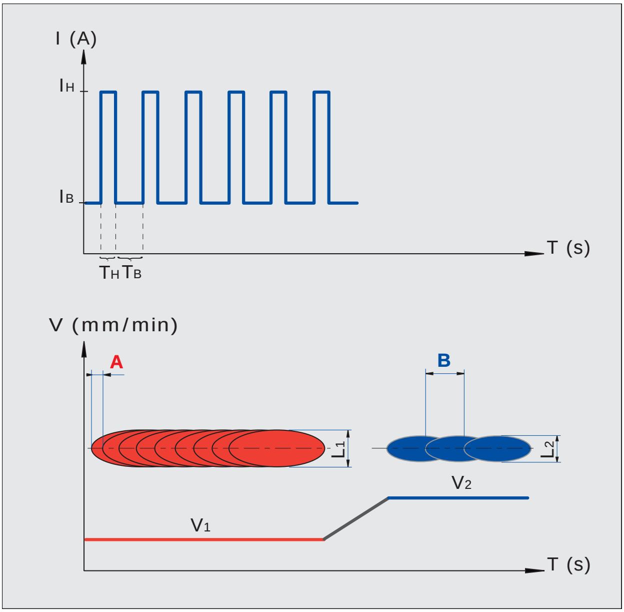


Fig. 9: Pulse welding and deposition rate

▶ The most conventional pulse waveforms are square although other types of pulsing may be used. Depending on the frequency, they will behave either as an optimised direct current to increase arc pressure (this is the case of rapid pulsing with a frequency of 500 Hz to 10 kHz), or as optimised conventional thermal pulsing (this is the case of monopulse-type pulsing which amplifies the impact of the high current of conventional thermal pulsing).

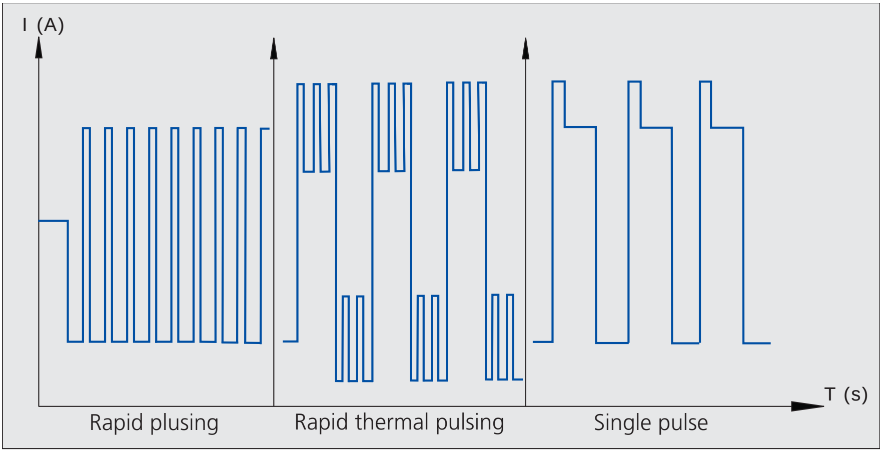


Fig. 10: Various pulsed TIG welding current waveforms

3.2.3. Arc ignition

In automatic welding, there are two common arc ignition techniques.

The first requires the use of an HF unit integrated into the power source capable of generating low intensity currents at high voltage (8 to 15 kV) at a frequency close to 50 Hz. The electron flow partly ionises the shielding gas making the arc column conductive and thereby creating a plasma.

As a whole, it is electrically neutral and composed of atoms of shielding gas, negatively-charged electrons, positive gaseous ions and metallic vapours.

The power source automatically detects the stabilisation of the arc and stops the high frequency emission.

This ignition technique is however limited by the difficulties involved in conveying high frequency through a great length of cable (30 to 50 m maximum). In certain cases, it is possible to move the HF unit by placing it as close as possible to the welding torch.

If not, and when the head is equipped with AVC (Arc Voltage Control), the arc can be ignited by using the method commonly known as a "lift arc" start.

This type of ignition requires a very brief short-circuit stage after which the controlled displacement of the electrode via the AVC slide is used to "draw" an arc until it is stabilised.

Once the arc is steady, the same slide is used in mechanically regulating the arc height (AVC).

Although requiring contact between the electrode and the workpiece as the current flows, this technique has often been approved to guarantee the absence of tungsten particle transfer on striking the arc. Furthermore, it appears that the absence of high frequency can also be considered as a token of reliability on complex (electronic) machines or when the isolation distances between welding torch bodies and workpieces are particularly short.

3.2.4. Weld current downslope

This phase characterises the transition from the steady-state welding current to complete cycle shutdown.

Downslope parameters are controlled by a current cut-out time and intensity. The resulting slope ensures that welding energy is gradually reduced.

The torch movement and oscillation amplitude (where applicable) also follow the same pattern to ensure a near-punctual stop. The wire is generally stopped just before the downslope is activated (except for high energy or fissuring materials where the wire is stopped as late as possible to limit the risks of a defect).

Management of this arc extinguishing phase ensures the elimination of craters, or even cracks at the end of the bead, frequently encountered on sensitive materials. Arc extinguishing currents are of the order of 1 to 15 A depending on working distances, electrode diameters and thicknesses to be welded.

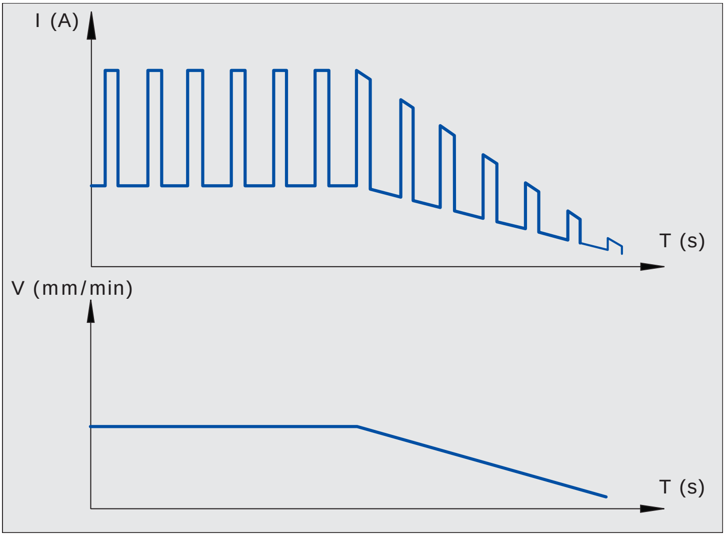


Fig. 11 : Diagram of a current downslope function

3.3. Welding gas

3.3.1. General

TIG welding requires the use of a shielding gas such as argon or helium.

For a number of specific cases, inert gas mixtures with a few active elements (H2, for example) in very low proportions (to increase the calorific value of the arc or reduce oxides) are available.

Various nozzles shapes or torch designs will adapt the gas flow to the morphology of the workpiece.

Depending on the installation, the following gases may be necessary:

- gases 1 and 2 (two gas circuits for the welding torch),
- trailing gas,
- backing gas.

There is also a "dual gas" function which has two inlets for a single outlet. In view of the ignition difficulties encountered with helium, the purpose of this function is to ignite the arc with argon and then, once the arc has been struck, to replace the argon with helium before starting welding.

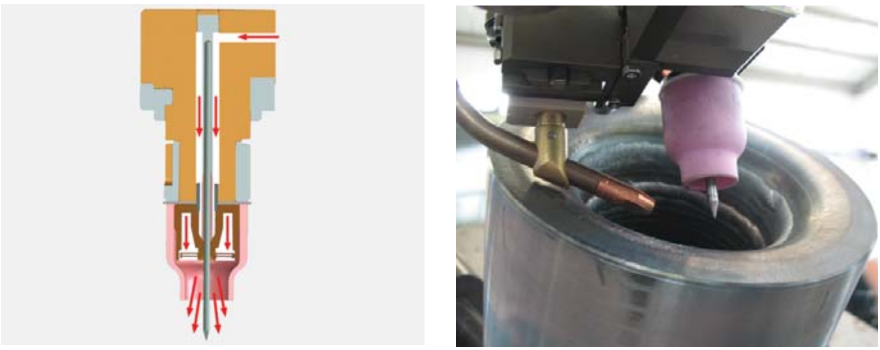


Fig. 12 : The gas lens ensures that the gas flow is evenly distributed around the electrode

The gas flow rate needs to be adjusted according to parameters, welding configuration, gas and torch type.

The stream must be as laminar as possible to avoid creating turbulence while preventing oxygen access. A flow rate that is too high or too low may end up having the same consequences on welding.

The signs to watch out for are the colouring of the beads and the electrode, ensuring where necessary that a good grinding angle is maintained and the tip remains free from erosion (it is assumed that the current is appropriate for the electrode cross-section, that the arc height is satisfactory and that the level of impurities in the weld pool is acceptable and does not generate any particular contamination phenomena).

Pre-gas is used prior to ignition to purge the entire system and guarantee a neutral environment before striking the arc.

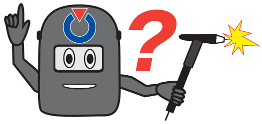
During welding, the gas flow shields the tungsten electrode, the weld pool and the solidification and adjacent areas against the effects of oxidation by the oxygen in the surrounding atmosphere.

After extinguishing the arc, post-gas maintains the shield until the torch, electrode and weld bead have cooled.

Post-gas will be maintained for a period ranging from a few seconds to almost a minute depending on the current intensities and the type of torch used.

The quality of the gas shield in TIG welding is also linked to its distribution. It is necessary to choose the torches, gas lenses and nozzles to guarantee the absence of oxidation on the basis of a range of issues, including access, the volume of the weld pools of the materials and welding position.

A stream close to the laminar mode is obtained by using gas lenses to ensure an even distribution of the gas flow at the periphery of the electrode.

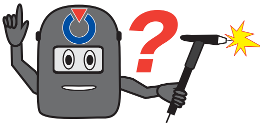


To adjust post-gas timing, make sure that the electrode has fully cooled. After the gas has been shut off, the electrode must be a tungsten colour without any discolouring.
Extra time may be granted over this minimum value to protect the bead in the downslope zone which should be as "white" as possible (except on a preheated workpiece where colouring quickly reappears until it is homogeneous with the rest of the workpiece).

Electrode stickout

The gas shield in TIG welding with a conventional torch is characterised by the diameter – or the output section of the nozzle – to which a flow rate adapted to the configuration of the workpiece is associated.

Generally, nozzles used outside of grooves have a larger diameter and require greater flow rates, especially as the electrode stickout tends to impose a slight increase in the gas flow also.



The choice of electrode diameter depends on the maximum welding current. The electrode must be sized on the basis of 1 mm of diameter per 100 A of mean current. For example, 3.2 mm electrodes can therefore withstand 320 A of mean current.
It is recommended to remain below this value where cycle times are long.

On the other hand, for nozzles positioned inside grooves, the output diameters are smaller and do not require a long electrode stickout. In this case, gas flows must be much lower.

As an initial approach, maintaining a constant flow rate-to-nozzle section ratio is a good way of coming to terms with the adjustment of a TIG torch flow rate.

When groove welding, the distance between the nozzle and the workpiece surface must generally not exceed 10 mm otherwise it may cause disturbance.

As a result, pauses must be made between passes (every two to four passes) to readjust electrode stickout and all of the related settings, such as the wire setting.

Where non-stop automation is an issue, special torches which adapt the electrode stickout during the cycle exist. In this case, the position of the motor-powered nozzle can be directly programmed in the welding sequence. This system is beneficial where the passes must follow on automatically or on welding progressive shapes.

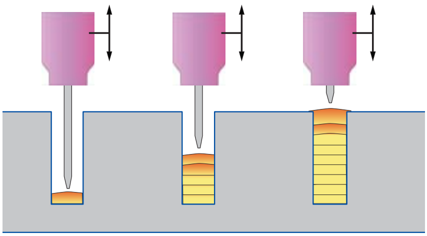


Fig. 13 : Powered correction of electrode stickout

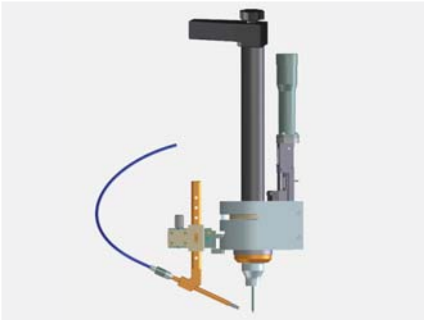


Fig. 14 : TIG torch with motor-powered nozzle

3.3.2. In-cycle control

To automate a TIG welding cycle, activation of the start and end points of the shielding phases must be controlled by a programme.

This is done by using solenoid valves which are directly controlled by start and stop functions positioned in the welding programme.

Furthermore, the presence of the various gases is also checked via the gas safety features installed on each circuit. The absence of gas before the start of the cycle disables the welding operation whereas a drop in the flow rate during the cycle will result in a downslope.

The flow rate is generally adjusted on a ball-type flowmeter located on the front of the power source. For more sophisticated machines, it is possible to use mass flow valves which enable the flow rate to be controlled directly by the programming function.

This feature was originally developed for keyhole management in plasma welding, but with today's multitorch machines, it enables the flow rate to be matched to the morphology of the torch without the risk of error.

3.3.3. Purging the installations

On commissioning an installation or when a machine has not been used for welding for some time, the entire gas distribution circuit must firstly be purged for much longer than the period for the usual pre-gas process that precedes each welding cycle.

In the case of delicate cladding operations, the residual oxygen in the inert gas must be measured using an oxygen analyser. Cladding cannot begin until the measured oxygen content has fallen below the preset value.

Fig. 15: Monitoring of the oxygen content in the welding gas and backing gas

In this case, the analyser can be interfaced with the power source to avoid starting an automatic cycle with an excessive oxygen content. The circuits can also be checked for leaks with this type of detection device in order to avoid contamination due to a handling error or component deterioration.

4. Particularities of the TIG cladding process

4.1. General

In the case of flat-position welding, a number of processes enable much higher productivity levels to be achieved: pulsed MIG welding, solid-flux welding or even variants with foil, and plasma welding with deposition via filler wire or powder.

However, several particular aspects plead in favour of TIG welding.

The first concerns complex surfaces where the ease of operation of the process is put through its paces, especially when cladding zones with corners, curves or inside or outside edges where the accuracy of the process avoids the need for manual touch-ups while maintaining a deposition rate of 1 to 2 kg/h. Separate control of arc energy and the quantity of metal deposited is an undeniable advantage when tackling tricky geometries (with the possibility of making passes of different thickness). The minor drawback of TIG welding lies in the fact that quite a high level of welding energy is transferred to the workpiece although, as the deposition rate is independent of the arc regime, extreme “saturation” is possible which optimises the ratio of welding energy-to-deposition rate according to workpiece typology. As a result, optimisation of the dilution rate is finally easier to achieve without neglecting the starts and stops to the detriment of layer regularity and surface conditions. In the event of an unforeseen incident, the welding sequences can be interrupted and resumed at any time. This start and stop control makes the micro-cracks and craters generally present at the

Fig. 16: Regularity of Hot Wire TIG cladding

start and end of beads made with other welding processes easier to manage.

The second strong point is position welding capability which gives operators greater flexibility and versatility in the perspective of workpieces which cannot always be suitably arranged for flat-position welding. Control of TIG welding parameters is highly advantageous in this case for position welding (pulsed welding) or in the case of very small-sized workpieces (cladding in bores less than 50 mm in diameter). Due to the flexibility of the process, it is possible to work with a very wide energy range with welding currents from 80 to 450 A (as an indication only). The corresponding deposition rates may vary from a few hundred grams to 3 kg per hour, occasionally by using two synchronised welding torches.

Fig. 17 : Cladding of small diameter workpieces

When a significant quantity of metal is to be deposited, TIG^{er} technology enables deposition rates approaching 6 kg/h to be achieved with a single torch and up to 10 to 12 kg/h with a double torch for flat cladding applications.

Another significant point relates to the ease of automation which makes it possible to work with several synchronised torches, or several wires to achieve productivity without affecting operability and the quality of the deposit. Even with several simultaneous arcs, all of the conventional functions used in TIG welding remain fully applicable (AVC, oscillation, synchronisation of movements with the welding currents, etc.).

The final, equally remarkable point concerns the relative neutrality of the deposits produced in Hot Wire TIG welding, such that the low oxygen content of the deposits does not affect the operative weldability of the following welding operations (unlike coated electrode or submerged arc welding deposits which can be “charged” with oxygen and present quite specific operative weldability characteristics that sometimes prevents position welding by an approach other than manual welding).

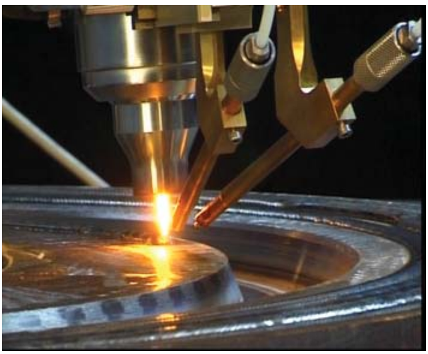


Fig. 18 : Example of torch configuration with a motor-powered nozzle and double Hot Wire

4.2. Dilution

The main difficulty encountered with cladding relates to controlling the dilution rate to guarantee the chemical analysis of the deposits.

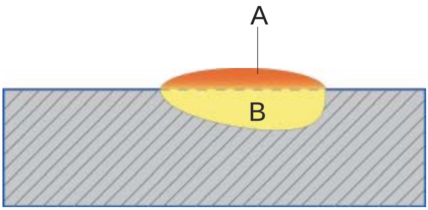
In general cases, the dilution principle characterises the result obtained after deposition on a substrate of another grade.

The alloys used for cladding are in fact listed for the specificity of their chemical analysis and their capacity to withstand external stress.

In most cases, performance is only guaranteed in a non-dilution condition, which means with a chemical analysis that corresponds to the classification of the grade.

However, in the scope of the welding operation, the filler product is melted completely and deposited on the parent metal (substrate) which is itself molten under the impact of the arc. The mixture of filler metal and parent metal characterises the dilution rate resulting from the cladding operation.

The search for a compromise between melting a minimum of parent metal while guaranteeing the quality of the bond with the deposit remains the major difficulty in defining operating procedures to ensure a balance between the compactness and the chemical analysis of the deposit.

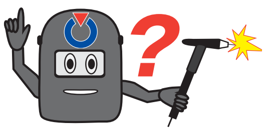


$$\% \text{ dilution} = \frac{B}{A+B} \times 100$$

Fig. 19: Dilution percentage calculation

The percentage dilution reflects the change to the chemical composition of the cladding alloy resulting from the mixture with the molten parent metal, or a layer that had already been deposited.

The effect of changes to welding parameters on dilution can be qualitatively assessed by a visual inspection of the cross-sections of the resulting welds. The section of the molten zone B below the surface of the substrate is divided by the total section of the molten metal A + B. The result is expressed as a percentage.



Welding energy is calculated as follows:

$$E\,(J/cm) = \frac{60\,U\,(V) \times I\,(A) \times \eta}{Vs\,(cm)}$$

η = efficiency = 0.6 in the case of TIG welding

A more precise assessment of the level of dilution is generally made by a chemical analysis of the deposits. Very often, the concentration of an element known to have a negative impact on the required characteristics of the coating is used as a reference limit to determine the validation of the effects of a welding procedure.

For example, in the original specification for the nickel-based alloy ERNiCrMo-3 (DIN W. No. 2.4856 Grade: NiCr22Mo9Nb), a material commonly used for this type of application, the iron content is limited to 5.0%. Consequently, some standards limit the iron content near the surface to 5.0%, which means that the tolerated dilution rate of the surface layer is close to zero.

Material	Content (%)
Nickel	58.0 min.
Chromium	20.0-23.0
Iron	5.0 max.
Molybdenum	8.0-10.0
Niobium (plus Tantalum)	3.15-4.15
Carbon	0.10 max.
Manganese	0.50 max.
Silicon	0.50 max.
Phosphorus	0.015 max.
Sulfur	0.015 max.
Aluminum	0.40 max.
Titanium	0.40 max.
Cobalta	1.0 max.

Fig. 20: Material composition limits of the nickel-based alloy ERNiCrMo-3 (DIN W. No. 2.4856 Grade: NiCr22Mo9Nb)

Note that for normal welding control, a two-layer deposit is commonly considered as all weld metal. The third layer, where required, forms a useful allowance where service constraints combine with mechanical wear of the deposits.

The essential parameters used in Hot Wire TIG welding are either those having a direct impact on welding energy, or those relating to control of the deposition rate.

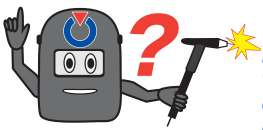
The main parameters are given below with related comments:

- Welding speed

This parameter affects energy and bead shape. Increasing the speed (with all other parameters remaining constant) reduces the bead width and, therefore, the contact area between the weld pool and the backing. This increase also modifies the bead geometry which, at constant deposition rate, tends to thicken the deposit.

- Welding current

This parameter affects energy to the same extent as the welding speed. The use of a high current guarantees performance to optimise the deposition rate. Direct-current welding is favourable to increased welding



In TIG welding with pulsed current, mean current intensity is calculated as follows:

$$I\,mean\,(A) = \frac{I_H\,(A) \times T_H\,(s) + I_B\,(s) \times T_B\,(s)}{T_H\,(s) + T_B\,(s)}$$

I_H = Pulse current intensity
I_B = Background current intensity
T_H = Pulse time
T_B = Background time

speeds for high-yield depositions. Pulsed-current welding requires a more modest speed range. In this case, current level adjustment is restricted to holding the weld pool in position and adapting the bead shape.

Pulsed-current welding can be used to increase the width of the beads at constant energy (advantage primarily used to achieve a regular appearance of the deposit in all positions - except flat and horizontal vertical positions - more easily).

- Welding voltage

Reducing the voltage increases the arc pressure and, consequently, tends to increase dilution in greater proportions than an increase in energy via the voltage would. It is preferable to consider this parameter when adjusting weld pool control conditions rather than considering a direct influence on dilution.

- Wire feed speed and heating intensity

These parameters are independent of arc control in TIG welding, however the calorie consumption required to melt the wire limits dilution.

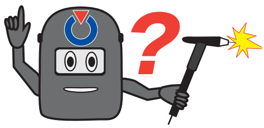
By linking the heating current with wire feed speed, the deposition rate can be significantly increased to a level approaching weld pool saturation. The quantities of deposited metal are several times higher than with cold-wire TIG welding.

- Preheating temperature

A temperature rise (or simply applying preheating) tends to increase the dilution rate. However, preheating is prescribed for metallurgical reasons with a view to limiting cooling rates in order to reduce the risks of fragile structure formation.

The preheating temperature, although having an influence, must not be considered as a parameter that can be used to control dilution, but the intensity setting must be adjusted as a result to limit arc power.

Irrespective of the influence on dilution, preheating can have positive effects on the mechanical properties of the coating. A preheated workpiece expands. After cooling (post-welding) of the coating deposited on the expanded workpiece, the coating is compressed. Depending on geometry, in some cases this stress condition limits sensitivity to cracking induced by stress corrosion.



For given welding conditions (current intensities, welding speed and arc voltage), there is a linear relationship between the wire feed speed and heating intensity.

Furthermore, as the Hot Wire principle is linked to the Joule effect and therefore the resistivity of the filler wire, these linear relationships will differ between unalloyed steels, stainless steels, titanium, etc...

As they are good conductors, Hot Wire TIG welding is of no benefit with copper or aluminium alloys.

▶ Welding technique and sequence

As far as the operational aspect is concerned, it is proven that the methodology selected for weld stacking has a strong influence on producing a notable reduction in dilution.

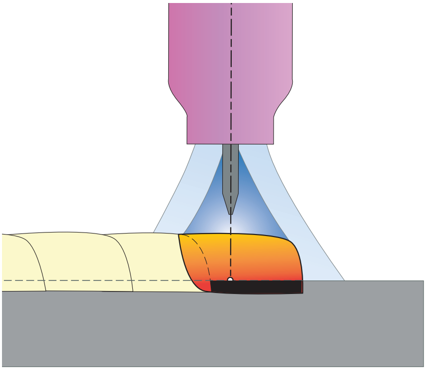


Fig. 21: Cladding a horizontal surface in the flat welding position. A large part of the substrate is struck directly by the arc resulting in greater dilution.

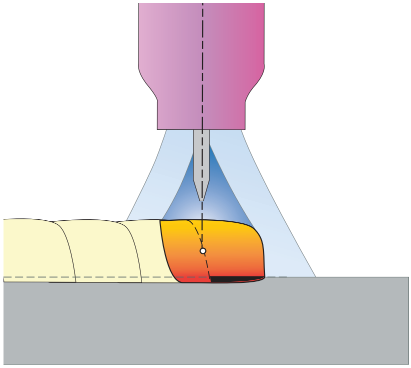


Fig. 22: Cladding a horizontal surface in the flat welding position. To reduce dilution to a minimum, each weld pass is essentially deposited on the previous one. Only a small part fuses with the substrate surface.

The use of torch configurations with a wire feed from the front or side avoids exposing support materials to the direct action of the arc. This arrangement has the advantage of reducing parent metal fusion by means of the filler metal positioned as a screen to capture most of the energy for the purpose of melting.

In cladding, as there is no bevel, wire feed from the weld pool side is possible unlike groove welding where the wire must be fed in the alignment of the joint plane of the two workpieces. A side wire feed simplifies torch design with the wire sheath running parallel to the torch body over the entire length up to the point where it enters the wire guide.

The wire angle in the weld pool has an influence on dilution, as the effect of pressure (vertical load) transmitted by the wire in the direction of the weld pool tends to increase the depth of penetration and, consequently, dilution. For this reason, it is preferable to work with wire feed angles of 60 to 70°, a setting range where the interaction between welding current and heating current is proven to be neutral. In fact, the interaction of the welding current and the wire heating current becomes non-existent as soon as the wire feed angle exceeds 45° in relation to the electrode axis.

This is why a direct-current heating source is frequently used for its versatility (use in welding and cladding for all front or side wire feed configurations).

In the case of TIG^er technology, use of an AC heating current prevents interactions between the fused arc and the wire feed; on the other hand, it is essential that the wire angles are

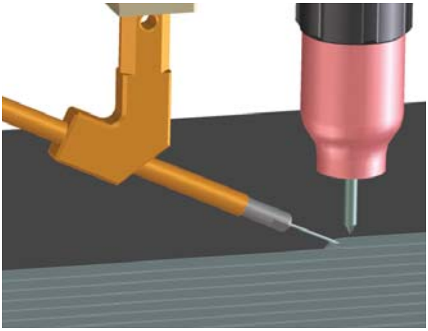


Fig. 23: Flat-position cladding. The hot or cold wire fed to the front of the weld protects the substrate from the arc and reduces dilution.

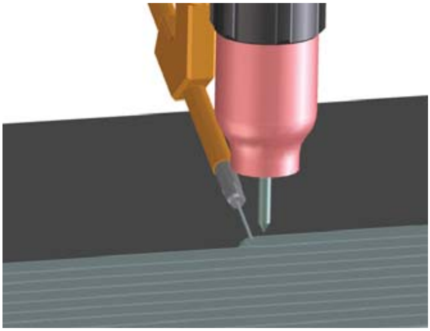


Fig. 24: Flat-position cladding. Hot Wire fed from the side, with wire impact again in front of the weld.

controlled to guarantee weld pool stability in spite of the very high wire feed speeds.

Other influential factors in limiting dilution are linked to the welding position and the electrode position as, by the same token as inserting the filler metal between the tungsten electrode and the workpiece, it is always possible to arrange it so that the weld pool is supported by the previous pass to keep the direct contact area between the weld pool and the parent metal as small as possible. Consequently, dilution occurs between weld metal and deposited metal instead of between weld metal and parent metal. This principle also applies when the TIG[er] arc offers very little penetration when the electrodes are oriented in the forward direction.

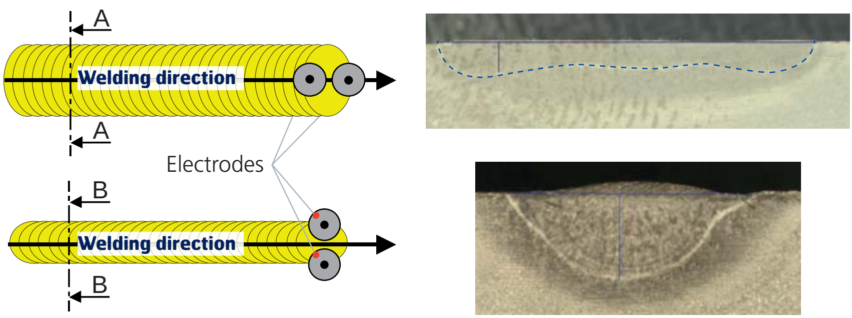


Fig. 25: Asymmetrical shape of the arc column and melting bath depending on the position of the electrodes

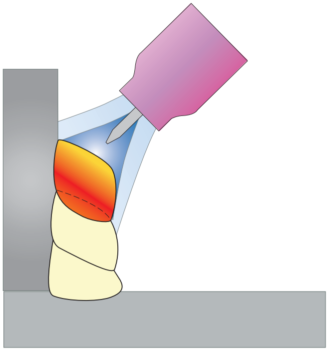


Fig. 26 : Cladding a vertical wall in the horizontal vertical welding position. Each weld pass is essentially deposited on the surface of the previous weld with less contact with the substrate surface.

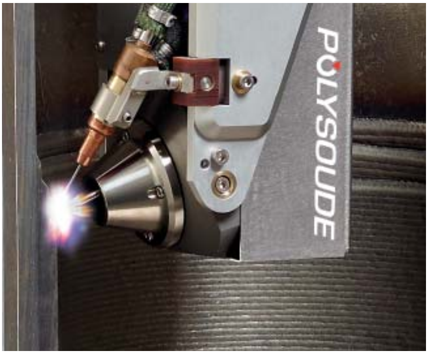


Fig. 27 : Cladding a vertical wall with the TIGer technology

▶ Number of layers

Dilution in the first layer between the filler metal and the parent metal does not generally allow the expected properties for the coating to be guaranteed.

Two cases are generally to be considered in defining the number of layers required.

1 - Welding metallurgy recommends the use of an intermediate layer to control the percentage of ferrite and limit the effects of fissuring (refer to the use of Schaeffler and Espy diagrams or equivalent notions).

Consequently, the second layer (corresponding to the deposition grade) must be used with a third layer which can then be considered as all weld metal (e.g. 16MND5-type steel-coated with a 309L layer + two 308L layers).

2 - Where the deposition alloy can be in direct contact with the substrate (parent metal), then two layers suffice (e.g. an unalloyed steel coated with a type 2.4856 nickel-based alloy).

TIGer applications correspond to the latter case. The quality target generally corresponds to a ferrite content of less than 5% at a distance of 3 mm from the fusion boundary for nickel alloy deposits. The facility to modulate pass thicknesses, the low average energy and the deposition rate enable values of 2 to 3% to be achieved from the second layer.

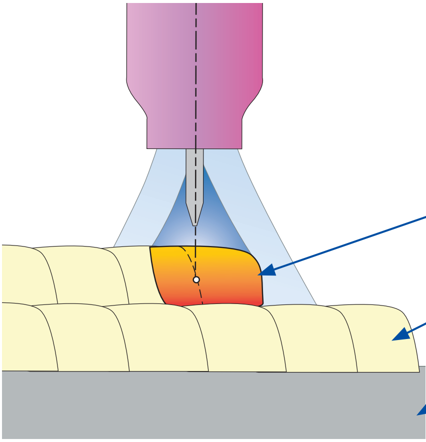


Fig. 28 : The dilution percentage decreases due to overlaying.

Fig. 29 : Sample of multi-layer cladding with a nickel-based alloy deposit (2.4856)

5. Cladding equipment

5.1. Power sources and equipment

5.1.1. Multifunction, computer-programmable power sources designed for precise control of current intensities and movements, and reliability in terms of process stability

The TIG welding power source is the heart of a cladding installation.

These features can be used as an interface with the operator for programming welding sequences. It is also equipped with electronics designed to run the current source and all surrounding functions to be controlled in order to master welding.

The power source is distinguished by:

- the 100% duty cycle which must be between 300 and 550 A according to the particularities of the applications,
- the performance levels of the programming system (possibility of creating dedicated application programs with features suited to cladding),
- the capacity to control the peripherals required for automation.

The open-ended structure of the Polysoude PC range of power sources makes it possible to adapt and add extra axes to control and programme the movements to be automated.

The instrumentation and control system (driven by microprocessors) has a modular structure for the programming of electrical parameters and the usual movements employed in TIG welding. The power source can therefore synchronise all of the functions required to perform the sequence and run, consecutively or simultaneously, the cooling system, shielding gases, welding currents, arc servo-control, oscillation movements, wire feed, speed settings, wire heating, peripheral equipment movements, parameter modification during the welding cycle and the stoppage of all axes following automatic or manual activation of the weld current downslope.

Fig. 30: Power source with adjustable instrumentation & control designed to steer the installation through all phases of cladding.

The axes controlling peripheral or external units include boards designed for turntables, positioners, booms, turning gear, collector-equipped cladding and welding heads, real-time data acquisition systems, coolers, oxygen control devices, etc. Other boards equipped with input and output ports can be programmed as logic circuits to disable or enable equipment operation according to the status of the installed safety devices. During a welding cycle, selected parameters may be modified via a connected computer or the installation remote control. These modifications are implemented immediately and do not interrupt the process. Furthermore, the operator can safely interrupt a cladding operation at any time thanks to a downslope function.

To monitor the welding process, the operator can be assisted by a video system.

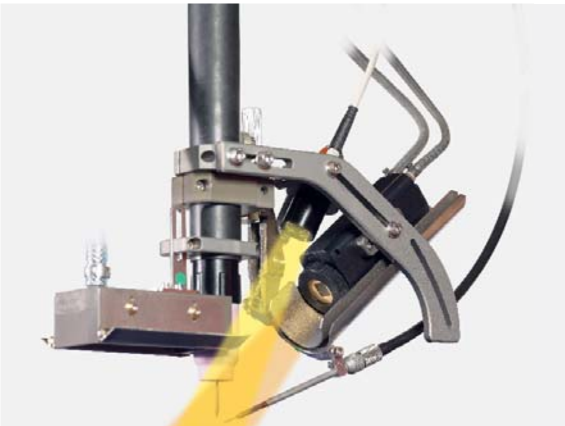


Fig. 31 : External camera on a WP 27 torch

This supplementary feature consists of cameras mounted near the torches (or integrated in more complex cases), umbilicals and a rack or container with the instrumentation and control functions (lighting and filter control, focal distance adjustment and viewing monitors).

Two cameras (positioned in front and behind) are generally required for welding whereas a single camera on the side is usually sufficient for cladding or buttering.

Depending on the level of integration, the cameras may be external with their own cooling circuit or replaced by micro-cameras installed in the bodies of torches specific to the application. In this case, it is not unusual to be faced with severe heat conditions combined with space constraints (for example, for internal cladding with a diameter of less than 75 mm with preheating to 150°C).

The POW software is used to programme sequences and adjust welding parameters. Related features simplify programme management (copying, modification and filing) and the input of conditions of use (type of materials, diameters, etc.).

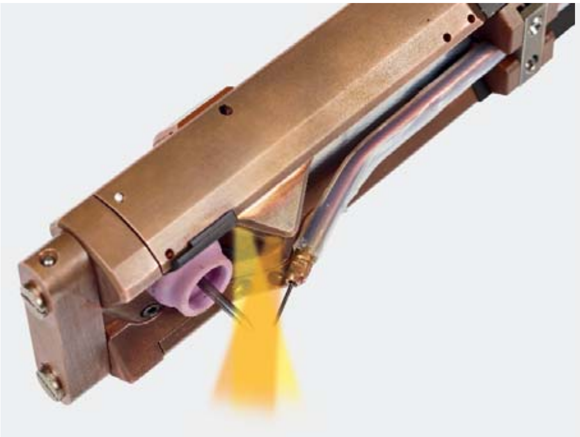


Fig. 32: Lance with built-in micro-camera

Other more technical features dedicated to the cladding activity supplement the basic programming. For example, the software incorporates a rotation counter for the development of programme loops for repetitive operations (cylinder cladding). Pass offsets are generally performed in step-over mode rather than continuous offset. The latter notably has the drawback of requiring very low variations for quite a long time, which poses motor control problems.

As far as cladding on circular backgrounds is concerned, the programme transparently takes account of changes in rotation diameter to work at a constant linear welding speed and thus guarantee regular deposition.

In the particular case of circular cladding, the central part requires particular know-how to obtain a deposit without the need for manual reworking.

The welding parameters and axis configurations (providing a soft interface between the various motors and the power source) are grouped together under programs stored in the programming device (rack or laptop computer) and transferred into the power source memory.

While the programs are running, the parameters can be modified from the programming device or via the remote control which relays the main functions within the operator's reach.

5.1.2. Positioning movements

Types of cladding equipment are differentiated by the configuration and design of the mechanical axes involved to enable the welding torch trajectory to be generated.

The I&C part of the power source controls the motors and drives of each axis to ensure the speed and displacement of each movement which can be operated independently or in a synchronised manner for those which have a direct effect on process control.

Cladding can concern a whole host of profile types (flat surfaces, external cladding on discs or cylinders, walls at the bottom of bores or complex shapes).

Fig. 33: Hot Wire TIG bottom cladding using the step-over technique. The welding speed is recalculated automatically according to the diameter of the turning circle.

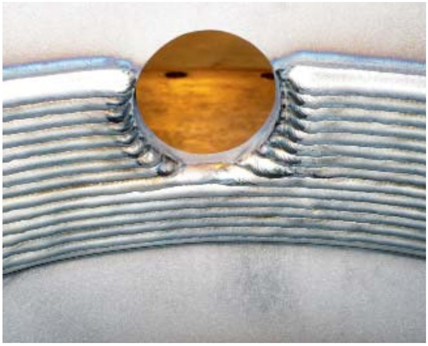


Fig. 34: Weld beads on a cylindrical wall, interrupted before a bore and continued on the opposite side.

Depending on space requirements and dimensions, welding torches or workpieces are set in motion to follow the various profiles with the possibility of synchronising the movement of several torches or simply synchronising the action of power sources where several torches are mounted on the same mechanical axis (e.g. a boom with a double torch).

5.1.3. Particular case of AVC and oscillation slides

These axes have a particular status as they intervene directly in the control of the welding process.

AVC is a device that comprises a powered slide, a measuring system and closed-loop regulation.

To achieve performance, this system requires the arc voltage to be measured if possible on the torch (close to the electrode) to limit the influence of line losses generated by the bundle lengths.

The AVC principle works on the direct relationship made (for a given current value) between the arc height and the resulting voltage value.

The electrode is used as a measurement sensor which means that, should it deteriorate, not only will the impact of the arc column be modified, but a second disruptive effect will modify the initial law between the distances and reference voltage.

In a normal operating range (over 30 A on welding under argon), AVC overcomes all irregularities to guarantee constant arc characteristics and enhance bead regularity as a result.

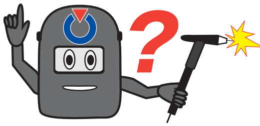
Various related functions help control the reaction of the AVC slide more finely to make it more reactive, to dampen its movement or to defer the effects on the weld pool.

Furthermore, the work phases of the AVC slide are programmed in the welding sequence and synchronised with the welding currents.

Out of welding, this axis is used to position the torch or to prepare the ignition sequence. One of the first steps in an automatic cycle is to stimulate workpiece detection by bringing the electrode into contact via the AVC slide movement. The point of contact is detected by the closure of the circuit between the electrode and the workpiece.

The oscillation axis is, to a lesser extent, used for positioning prior to welding where automatic positioning is necessary in relation to one or two reference edges (e.g. centring in a groove or positioning in relation to a reference face).

During welding, this axis may perform an oscillation movement in synchronisation with the welding current or will enable the trajectory to be reset or offset (e.g. step-over).



AVC works on the principle of closed-loop voltage regulation. For the same welding conditions, a given voltage corresponds to an arc height. This correspondence between voltage and arc height requires the electrode – which acts as a "measuring instrument" – to remain in perfect condition.

Several situations may accidentally result in variations in arc height:
- variations in the grinding angle,
- electrode contamination (collar),
- abnormal overheating (cooling problem or incorrect size).

Observation can therefore reveal much about possible AVC instability.

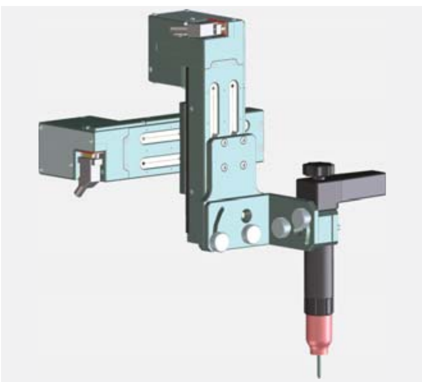


Fig. 35: AVC and oscillation slides with TIG torch

5.2. Installation designed for flat cladding on a fixed workpiece

Cladding installations for flat-position welding of fixed workpieces generally comprise an appropriate workpiece support (table or cradle) and a boom equipped with a end interface (torch, AVC and oscillation slides, wire feed unit and cable/hose bundle for power, fluids and movements).

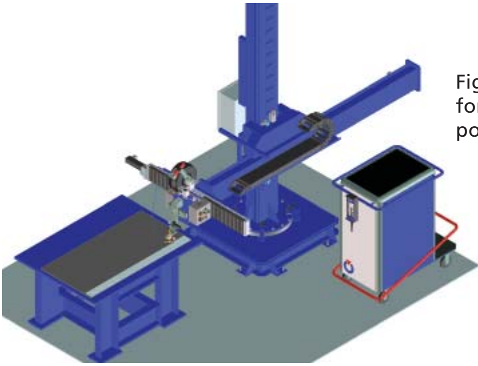
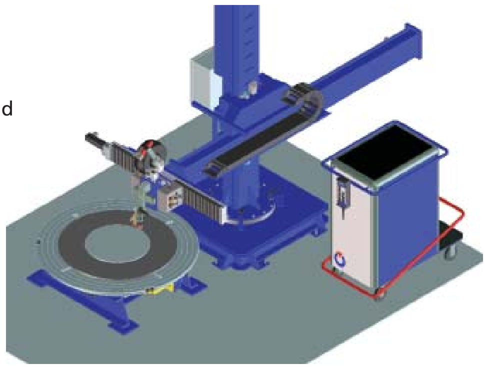


Fig. 36 : 3D view of an installation designed for cladding fixed workpieces in the flat position

5.3. Installation designed for flat cladding on a rotating workpiece

Cladding installations for flat-position welding of rotating workpieces are identical to those designed for fixed workpieces apart from the use of turning gear, a turntable or positioner to control the movement of the workpiece.

Fig. 37 : 3D view of an installation designed for cladding on a turntable



The welding power source from the PC range controls the whole cladding sequence and drives each of the movements and peripherals to produce a complete layer.

Machines of this type are characterised by the capacity of the booms and positioners according to the weight and geometry of the workpieces.

This type of installation is designed for an overall duty cycle of 465 A at 100%.

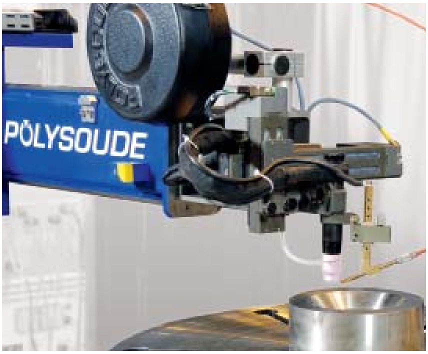


Fig. 38: Example of an installation designed for cladding nozzle end-pieces

The figure below shows the result of a cladding operation during which a layer of ERNiCrMo-3 nickel-based alloy is deposited on an AISI 4130 grade (25 CrMo 4 1.7218) workpiece.

Fig. 39: AISI 4130 (25 CrMo 4) sample with an ERNiCrMo-3 deposit. Welding was continuous with automatic speed adjustment according to the diameter of the turning circle.

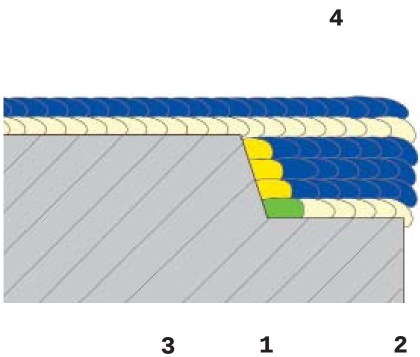


Fig. 40: Weld pass distribution diagram

Information relating to the "Weld pass distribution diagram":

▶ Pass 1 is particular as it requires a greater contact area with the parent metal (the conditions are closer to the production of a groove weld).

Due to its dilution and the risks of insufficient compactness in the corner, and under the effect of stress, this pass must be completed with specific parameters (increased energy and reduced deposition rate, if necessary).

- The parameters of weld passes 2 in contact with the parent metal have been adapted to limit dilution (energy = 0.38 kJ/mm). The substrate is melted, the HAZ is less than 2 mm thick and the deposit is around 2.8 mm thick.
- The parameters of weld passes 3 are similar to passes 2.

The horizontal vertical position helps limit dilution while ensuring compactness and the bond with the parent metal.

- Weld passes 4 are not in direct contact with the parent metal. The parameters are optimised with a productivity target (0.42 kJ/mm for a thickness of 3.3 mm with a deposition rate of 1.64 kg/h).

Note that chemical analyses are within the surface criteria from the second layer.

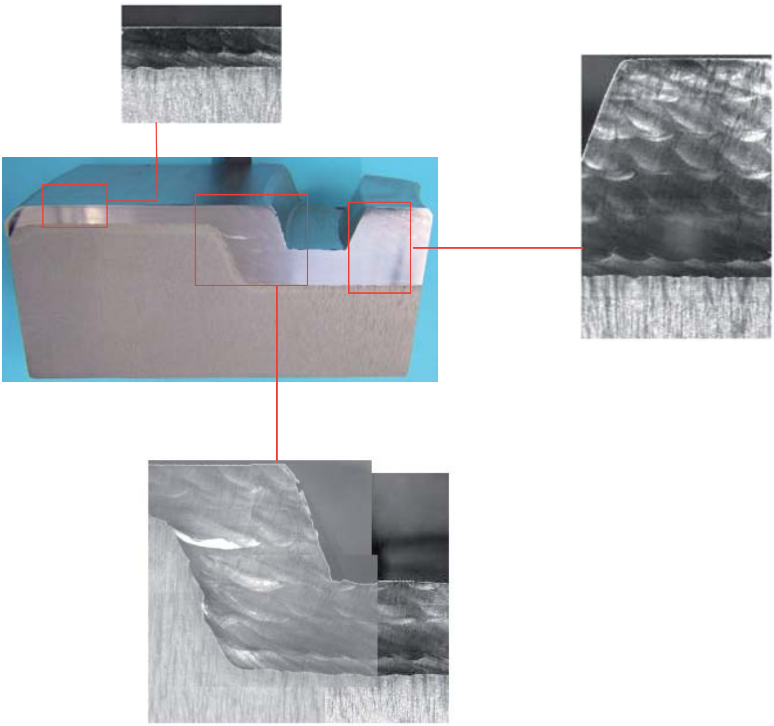


Fig. 41 : AISI 4130 (25 CrMo 4) sample with a 2.4856 deposit: macroscopic cross-section of the substrate and coating.

5.4. Installation designed for cladding in a vertical position

This is a conventional machine configuration to perform cladding operations on cylindrical parts.

Depending on the torches used, welding may be performed on the outside diameters or on the inside faces of bores.

This configuration is ideal and provides the best compromise between efficiency (deposition rate) and dilution.

The workpieces are positioned and clamped on a turntable or positioner.

The surfaces to be coated must be concentric to the table's axis of rotation.

The welding torch is installed on a set of crossed slides (AVC and oscillation). The slide strokes are adapted to the dimensions to be clad.

To clad deep bores, the equipment must have the capacity to support cladding torches up to 2.5 m in length together with vertical slides with an equivalent or greater stroke than the torch lengths.

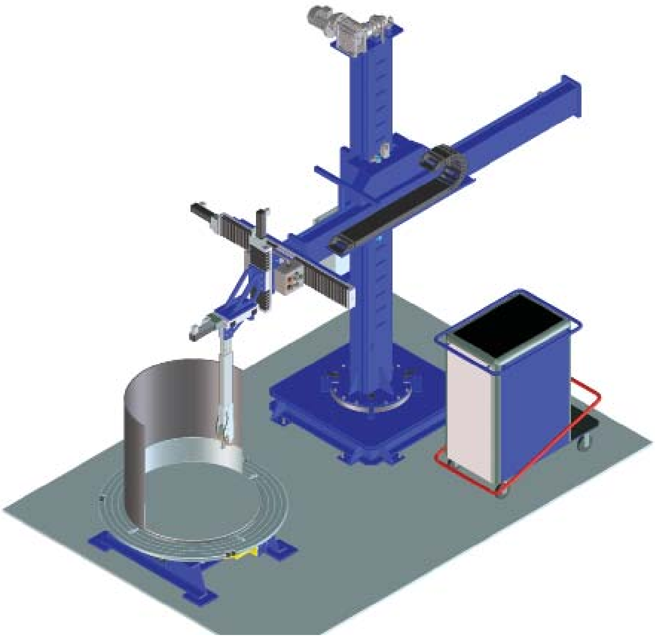


Fig. 42 : 3D view of an installation designed for cladding cylindrical parts in the horizontal vertical position

Due to their configuration, these machines are relatively versatile and can perform the same operations as rotating machines for flat-position welding.

Consequently, to perform cladding operations at the bottom of bores, specific torches are dedicated to each of the configurations (straight torches for the bottoms, torch at 90° for the walls, torch at 45° to 60° for the corners).

Torch variants exist for welding with one or two filler wires or with adjustable tilt angles.

For small diameter bores (up to 50 mm), cold-wire TIG welding solutions with integrated video are available.

Fig. 43: Welding lances dedicated to internal cladding. There are single and double-wire versions and the angles are adapted to the various operations (wall, bottom and wall/bottom contact angles). The bodies are cooled to withstand the interpass temperatures.

Fig. 44: Lance with powered tilt for 309L-308L coating on internal blend radius of a nuclear power plant steam generator nozzle.

Fig. 45: Cladding in the horizontal vertical position on a large-sized cylindrical work-piece with a specific slide for the vertical stroke.

5.5. Cladding installation with collector-equipped heads

There are other, much more complex scenarios where it is impossible to set the workpieces in motion, either due to their size and weight, or quite simply because of their geometry (e.g. drilled holes in solid workpieces or oblong shapes).

A family of tools (orbital head tools with endless rotating collector) has been specifically designed for such situations as the torches can be rotated without twisting the cable/hose bundles. These machines can take care of cladding operations on fixed workpieces with a high level of automation.

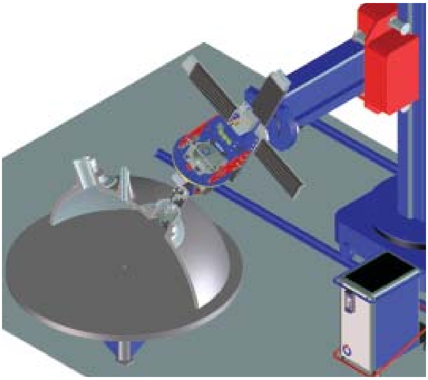


Fig. 46 : 3D view of an installation with boom and collector head designed for cladding bores on fixed workpieces. The slide supporting the head provides the vertical movement. The assembly is mounted on a directional support to clad bores without necessarily having to adjust the parts to be clad.

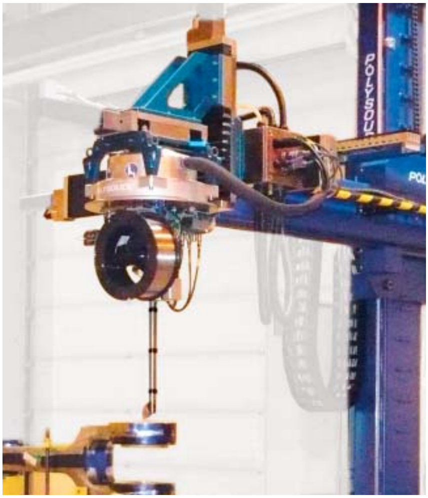


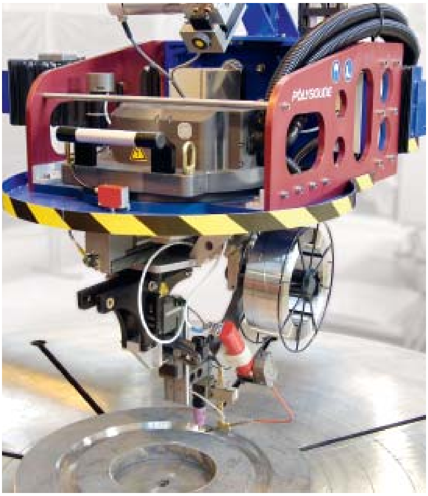
Fig. 47 : Example of a 45° internal lance mounted on a collector head. The head is equipped with a special plate for rapid torch changeover. A horizontal slide adapts the assembly to the diameter to be welded.

Arc voltage control (AVC) slides, oscillation slides, wire feeders and video equipment are mounted on the plate just like on a conventional orbital head. The essential variant generally relates to the severe environment requiring robust components capable of operating almost around the clock.

The surfaces that can be clad with these rotating machines are the same as in situations where the workpieces are in motion except that such equipment is to be reserved for more difficult cases such as deep, small diameter bores or internal cladding in all positions.

In more extreme scenarios, either due to the shape to be clad (e.g. oblong holes) or to the geometric characteristics of the workpieces (1 to 2 m deep bores), it is quite common to use "mixed" installations. The collector-equipped orbital head is then suspended at the end of a boom via several crossed slides above a turntable.

This architecture is by far the most versatile tool for industrial companies looking to maintain a high level of flexibility in their machine range.



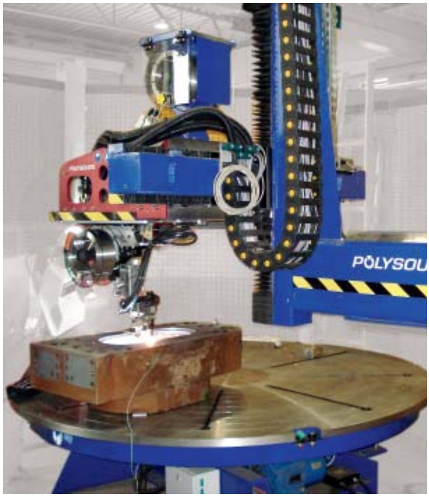


Fig. 48: Example of equipment designed for cladding oblong shapes for valve bodies used in the oil industry. The welding head is held and positioned by two slides at the end of the boom. The trajectory is obtained by composing movements from the 180° torch rotations on the head and travel on the slide. With the collector installed on the orbital head, continuous welding is possible due to the absence of bundles.

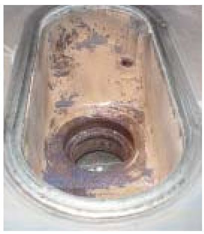


Fig. 49: Detailed view of a cladding profile with composite movements. The operating procedure is fully automated.

5.6. Installation designed for the internal cladding of tubes in a horizontal position

5.6.1. Deposits less than 2 m long

Internal cladding of tubes for lengths of less than 2 m (or 4 m with turnover) is performed on installations which can rotate the tubes supported by non-motor-powered turning gear. The turning gear has an adjustable diameter which consequently displaces the theoretical axis of the tubes to be clad. The tubes are clamped and rotated by two chucks of a height-adjustable hollow-shaft positioner to take account of the range of various diameters to be welded. The positioner hollow shaft is not essential for short tube lengths (possible overhang limitation). Up to an internal diameter of 140 mm, the coating is made with a single Hot Wire TIG torch.

For applications from 150 mm, productivity is improved by using double Hot Wire TIG torches.

The torch is slightly oriented such that it can place the bead to be made on the previous weld pass, thereby reducing the rate of dilution with the parent metal.

Cladding is performed by withdrawing the lance out of the workpiece.

The synchronised movement of the rotation and the horizontal arm generates the step-over on each rotation.

When cladding short lengths, the AVC slide is placed outside the tube at the end of the lance.

For long sections (1 to 2 m), the AVC slide is mounted on the welding lance.

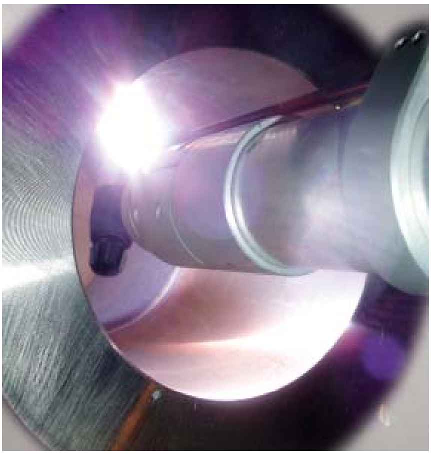


Fig. 50: Internal coating less than 2 meters in length with simple-wire welding lance

Fig. 51: Short internal cladding (external AVC not visible) with internal lance with double Hot Wire feed. Generally this type of coating is performed in a continuous operation and requires external tube cooling to guarantee remaining below recommended interpass temperatures.

5.6.2. Deposits up to 12 m long

Industrial solutions have been developed for the internal coating of standard tubes (6 to 12 m long).

The philosophy is identical to the machine described in section 5.6.1, except that a special device has been developed to support the welding lance over its entire span.

The difficulty lies in guiding the torch in a highly demanding environment (small tube diameter and temperature inside the tube during the operation).

The solution that has been proposed and tested requires a torch guiding system based on the construction of a bench of around 12 m in length which is combined with a system using tendon cables (2 to 3 ton load), the span of which is equal to the length of the tubes to be clad, plus passages in the mechanisms used to set the tension and block the tendons.

The tendons are fed through the tubes, then tightened to limit welding lance deflection.

The lance, equipped with two welding torches each with a double Hot Wire feed, is deployed to the end of the tube.

Welding is then performed by pulling the welding lance. Two Hot Wire TIG power sources are synchronised with each other and with the torch support carriage forward and rotation movements.

Fig. 52: Installation for internal coating of 12 m long tubes. Close-up of the carriage supporting the two wire spools. The lance is supported by tendons (centre of the photo) to limit torch deflection.

Fig. 53: View of the lance resting on the tendons designed to limit torch body deflection. The lance is equipped with two double-wire torches to deposit the two layers simultaneously. The ends are controlled by restarting operations (control of the pitch between the two torches).

Fig. 54: As a variant, a lance equipped with two torches adopting the TIGer technology with a single Hot Wire can also be used to produce two layers simultaneously.

Welding is identical to that used on coatings less than 2 m long.
Step-over is controlled in the same way with the two torches.

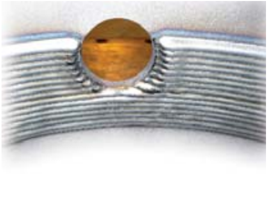
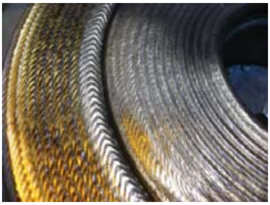
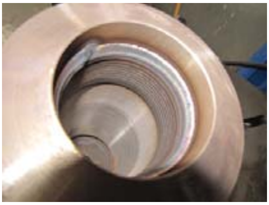
Fig. 55: Long tube prepared to receive internal coating. Secured and rotated by the hollow-shaft positioner mounted with vertical adjustment, the tube is supported by the turning gear. The welding lance slides on two tendons tightened by the tensioning system in the foreground.

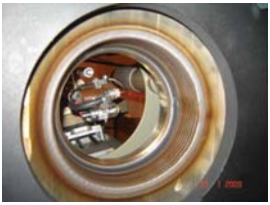
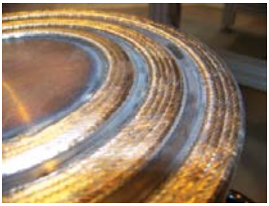
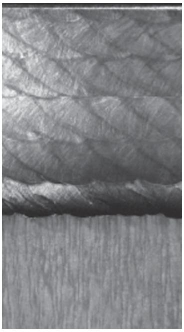
6. **Conclusion**

The Hot Wire TIG welding process is a benchmark in the area of automation for high-quality coating or buttering operations. There is no question of replacing other processes where such a choice is appropriate but this technique should be considered where the shapes to be clad are complex, where space constraints are severe or quite simply a higher level of automation is desirable.

A range of standard equipment and several specific solutions are available to cover the diversity of applications.

Polysoude is able to recommend existing tools, provide assistance regarding use or develop equipment in response to customer expectations.


7. Appendices

Technical characteristics of cladding installations configured in different ways.

Installation for cladding rotating workpieces in flat position

Examples of workpieces for coating:

Valve plates, caps, guide rails, valve slides, etc.

Equipment

- One 4 x 3 m boom
- Slides, 2000 mm vertical stroke x 1000 mm horizontal stroke
- One 500 kg turntable
- One PC 600 type Hot Wire TIG welding power source
- One AVC, 110 mm stroke with electromagnetic brake
- One cross slide, 300 mm stroke with electromagnetic brake
- One liquid-cooled 500 A WP27 TIG torch

Workpiece characteristics	Welding parameters	Deposit
Parent metal: AISI 4130 OD/ID: 165/84 mm Preheating: 150 - 170 °C Interpass temperature: max . 270°C	Wire filler *Material*: ERNiCrMo-3 *Diameter* : 1.2 mm *Hot Wire current* : 60 A *Wire feed speed*: 1 800/3 100 mm/min Welding gas *Type*: Argon *Flow rate*: 25 L/min	Layer thickness: 4.6 mm Bead width: 6 mm Deposit rate (top pass): 1.57 kg/h Number of layers: 2 Speed of linear displacement: 350 - 400 mm/min Dilution (top layer): < 3% HAT thickness : 2 mm

Installation for cladding rotating workpieces in flat and horizontal vertical position

Examples of workpieces for coating:

Shorts tubes, bores, cylindrical parts, etc.

Equipment

- One 4 x 4 m boom with 180° manual rotation
- One 1.5 tonne turntable
- One PC 600 type Hot Wire TIG welding power source
- One vertical slide, 1000/2000 mm stroke, mounted at the end of the boom, 0°/90° positions
- One torch adjustment slide, 200 mm stroke with electromagnetic brake
- Two Hot Wire feeders
- One liquid-cooled 500 A WP27 TIG torch

Workpiece characteristics

Parent metal: Unalloyed steel

Diameter : 200 - 2 000 mm

Preheating: ≤ 150°C

Interpass temperature : ≤ 300°C

Welding parameters

Filler wire : Two 15 kg spools

Material : ERNiCrMo-3

Diameter: 1.2 mm

Welding gas

Type : Argon

Bottom cladding

Welding tools	Deposit
Welding lance, 2 000 mm long. Torch angle: 180°	Layer thickness : 6 mm Bead width: 6 mm Number of layers: 2 Speed of linear displacement: up to 250 mm/min

Wall cladding

Welding tools	Deposit
Welding lance, 2 000 mm long. Torch angle: 45°	Layer thickness : 4 mm Bead width: 6 mm Number of layers: 1 Speed of linear displacement: up to 250 mm/min

Installation for cladding fixed workpieces

Examples of workpieces for coating:

Valve bodies, bores, oblong or eccentric chambers, etc.

Equipment

- One 4 x 4 m boom with 180° manual rotation
- One SPX collector head
- One PC 600 type Hot Wire TIG welding power source
- One SPX collector head adjustment slide, 200 mm stroke with electromagnetic brake
- One Hot Wire feeder
- One welding lance

Workpiece characteristics

Parent metal: Unalloyed steel

Diameter: 50 - 300 mm depending on welding lance used

Preheating: ≤ 150 °C

Interpass temperature: ≤ 300°C

Welding parameters

Wire filler: One 5 kg spool

Material: ERNiCrMo-3

Diameter: 1.2 mm

Welding gas

Type : Argon

Cladding 50 to 100 mm and 100 to 300 mm bores

Welding tools

Lance for 50 100 mm dia.

Lance for 100 à 300 mm dia.

Length: 600 mm

Torch angle: 45°

Deposit

Layer thickness : 6 mm

Bead width: 6 mm

Number of layers: 2

Speed of linear displacement: up to 250 mm/min

Note: Depending on torch type and the presence of a tilt angle upstream of the collector head, the machine will be operational in the flat position, in the horizontal vertical position or all positions for bores.

Installation for the internal cladding of tubes in a horizontal position

Rotating workpiece

Examples of workpiece for coating:

Tube interiors.

Equipment

- One positioner with hollow shaft and double chuck, speed of rotation from 0.1 to 1 rpm
- Two sets of adjustable-diameter turning gear to support the tube
- One welding lance, 13 m long, equipped with two TIG torches, AVC and Hot Wire feeders.
- Two synchronised PC 600 type Hot Wire TIG welding power sources

Workpiece characteristics

Type: tubes

Parent metal : Unalloyed steel

Wall thickness: 12-76 mm

Length: 3, 6 or 12 m

ID : 150 à 600 mm

Preheating : ≤ 150°C

Interpass temperature: ≤ 300°C

Welding parameters

Filler wire:

4 15 kg spools

Material: ERNiCrMo-3

Diameter: 1.2 mm

Welding gas

Type : Argon

Cladding the inside of 150 to 600 mm dia. tubes

Welding tools

Lance for 50-100 mm dia.

Lance for 100-300 mm dia.

Length: 13 m

Torch angle: 45°

Deposit

Layer thickness: 6 mm

Bead width: 8 mm

Number of layers: 2

Number of lance layers: both layers are performed simultaneously in a single operation

Speed of linear displacement: up to 600 mm/min

Installation for the internal cladding of tubes in a horizontal position

Rotating workpiece

Examples of workpiece for coating:

Internal cladding of bi-metallic tube ends.

Equipment

- 1 positioner with hollow shaft between tube end and internal clad tube
- 1 PC 600 type master power source
- 1 slave power source equipped with a PC 600 type current source
- 1 wire-heating current source (AC)

Workpiece characteristics

Type: tubes

Metals:

Parent metal: X42 - X70 type unalloyed steel

Clad tube: 304 L ou 316 L

Length : 11.7 à 12.5 m

I.D. : 168 à 508 mm

Preheating: ≤ 150 °C

Interpass temperature: ≤ 350 °C

Welding parameters

Filler wire:

15 kg spool

Material: ERNiCrMo-3

Diameter: 1,2 mm

Welding gas

Type: Argon

Internal cladding of 168 à 508 mm dia. composite tube ends

Welding tools

TIG^{er} lance

Length: 800 mm

Deposit

Layer thickness: 1.5 to 3.5 mm

bead width: 3 to 3,5 mm

Number of layers: 2

Speed of linear displacement: up to 750 mm/min

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