The root penetration side: an area that is often forgotten

By Ko Buijs, Metallurgical Consultant, Van Leeuwen Stainless Holland

In practice, the quality of a welded joint in pipe systems is often judged by what you see on the outside. However, just because a welded joint looks very nice and beautiful on the outside, does not automatically mean that it is of the required quality (see illustration 1). This is particularly important in the case of stainless steel. This is the reason why more and more and more welding work is being checked with an endoscope so that you can perform a detailed inspection of the inside (i.e. the root penetration side).

During welding, an inert backing gas is normally applied to the inside of the tube, in order to prevent oxidation of the material. If it is allowed to occur, oxidation can cause the surface of the stainless steel to become burnt and thus porous, so that for example a relatively small chlorine ion can penetrate deeply in order to do its destructive work. In other words, the darker the burning is, the more porous the surface will be, so that the extent of corrosion on the root penetration side depends to a great degree on the discoloration of the welded joint. In general, you can assume that straw-yellow discoloration is still acceptable. However, in practice, this discoloration is often much darker, and can even be extremely dark. If discoloration exists (even after backing gas has been used), you can restore stainless steel to its previous condition by using a descaling process that can even be performed by mobile personnel.

'Not necessary to use backing gas'

In addition to possible discoloration, you can also obtain pockmarked and/or rough root penetration that has an adverse effect on the corrosion resistance. Moreover, this forms an ideal breeding ground for all kinds of undesirable microorganisms. All of these factors directly affect the efficiency of the welder and the quality of the equipment that he uses. In practice, you will often hear the comment: 'it is not necessary to use backing gas because it is only water that must pass through'. However, such welded joints usually leak within one year, even when AISI 316L is used. Many poignant examples can be encountered. For example, illustration 2 shows an AISI 316L pipe that already leaked after only 15 months when it was used for cold river water. After gaining access to the inside, the heavily burnt root penetration side was clearly visible. It also goes without saying that this extent of corrosion damage has severe financial implications. For example, on a sea ferry, the welded joints on an AISI 316L pipe that was several hundred metres long, became severely corroded after approximately 1 year, because static extinguishing water containing a small amount of chlorine bleaching lye proved to be too aggressive for this stainless steel. In fact, you must be aware of the fact that the burnt root penetration is not able to withstand this kind of corrosion. Moreover, in this case, backing gas was not used, and the welded joints of the pipe now leak like a veritable sieve. In fact, there is only one solution, i.e. to renew the entire pipe, even though this would be extremely expensive, because the ceilings of all the cabins, corridors, restaurants, etc. have to be opened up, not to mention the loss of income during the period when the ship would have to be temporarily taken out of service.

Picture 1. This fire-extinguishing pipe in 304L was apparently welded satisfactorily (see below), but the root penetration side (see above) was so bad that the pipe started to leak at these locations within a relatively short time.

Picture 2. Leaking AISI 316L cooling water pipe because backing gas was not used. The burnt root penetration side can be seen on the lowermost illustration.

Thus, the casual attitude and expression 'it is only water' have resulted in dire consequences. Many corrosion experts will tell you similar stories. Even though you thought that the installation was not expensive, the motto 'cheap is expensive' is also applicable to this sector. You only obtain corrosion resistance if you allow the passive oxide film to fulfil its function and this is often underestimated. Burnt stainless steel has an active surface, and after a relatively short period of time, even water will burrow its way through the wall as a kind of chemical drill. The pockmarked and rough character of the root penetration is thus undesirable for optimal corrosion resistance, and this also encourages all kinds of microorganisms and bacteria to be attached, thus adversely affecting the quality of the product that has to flow through the pipe.
Waterworks companies take the view that it is not necessary to use backing gas during welding, because the drinking water is always so mild. Illustration 3 shows a painted AISI 304L main pipe that leaked directly beside the circular seam joint after approximately 1 year.

It is therefore extremely important to ensure that the root penetration is as smooth and bright as possible, but then you also have to rely on the personal and often limited skills of the welder. However, you can eliminate these effects by using new digital welding techniques that have been recently developed. The ultimate example of these new techniques is the ServoTig welding machine that is equipped with a root penetration sensor that is also referred to as Automatic Penetration Control (APC). You can make a comparison by looking at such a welded joint in illustration 4.
The relevant stainless steel tube has been sawn open so that you can observe the root penetration in detail. Moreover, this type of internal surface has superior corrosion properties and is virtually unsusceptible to the attachment of all kinds are undesired substances. These types of welds are thus destined to become extremely popular because they do not to depend on the skills of the welder. Moreover, these welds are also extremely easy to clean because the pig is not obstructed by protruding welding beads.

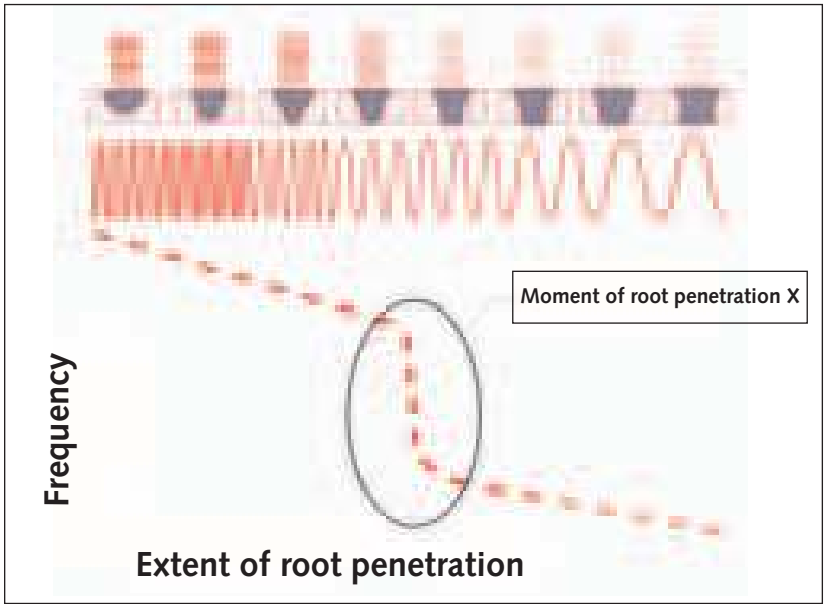
Orbital welding of stainless steel

During orbital welding, use is made of the TIG (tungsten electrode with inert gas) welding process where the base metal is fused in order to form the weld. Generally, welding additive metal is not used, although this is possible. You can work with closed or open heads, and the latter is necessary if you still wish to use welding additive metal (see illustrations 5 and 6). During the welding, an arc is formed between the tungsten electrode and the workpiece. In order to start the arc, the forming gas is ionised by a high frequency or high-voltage peak, so that a path is created for the welding current. A capacitor provides current for the arc so that the arc voltage drops to a level that allows the power supply to be controlled. The power supply reacts to the demand for power and supplies current to maintain the arc. ▶

Picture 3. A corroded AISI 304L main pipe from a water extraction company that leaked after 1 year because backing gas was not used.

Picture 4. Perfect root penetration thanks to APC (Automatic Penetration Control).

Picture 5. Enclosed Servo Weld heads. Basic version enclosed digital weld heads.



Graph 1. Graphical representation of the moment of root penetration.

Choosing orbital welding is justified for the following reasons:

- Productivity. An orbital welding machine has a much higher productivity than welding by hand, provided that many similar welds must be made and that sufficient attention is paid to training and root penetration checking.
- Quality and consistency. In fact, for the pharmaceutical industry, orbital welding is the only process that can satisfy the required quality and consistency levels. The quality and reproducibility of welded joints made using conventional orbital welding and controlled by a correct welding program is by far, superior to joints that result from welding by hand. However, there is no guarantee that that the root penetration will be optimal because the production weld must always be made under different conditions, thus extra checking is always required.
- Certified welders are increasingly difficult to find. In most cases, a certified operator is required for orbital welding equipment, unless you use a root penetration sensor.
- The orbital welding process can sometimes provide the only solution in those cases where pipes or tubes cannot be rotated when performing the welding work. It is also used in locations that are inaccessible for other welding procedures. For example, an orbital welding system is recommended for welding tubes and tube plates, where the welder cannot gain easy access with his welding torch or finds it difficult to check the welds that have been made.

In the meantime, conventional orbital welding procedures have become increasingly common as welding processes. However, since a process with a root penetration sensor is completely new and unique, we will now provide a brief description of this promising technology. The ServoTIG machine has been developed by Dynamicc Welding B.V. in Coevorden, The Netherlands.

ServoTIG

ServoTIG welding is a combination of the TIG welding process with a root penetration sensor and Weldvision. In other words, this is a TIG welding process that performs its own checks. The root penetration sensor enables the melting bath vibrations (i.e. melting bath oscillations) to be measured, so that this data can be used to control the required energy during the melting bath phase, in order to achieve a perfectly controllable root penetration. The root penetration sensor from Dynamicc Welding B.V. operates on the basis of measured melting bath oscillations. Because a relationship exists between the melting bath frequency and the level of root penetration, the ServoTIG determines the time of root penetration itself. In other words, this is an intelligent root penetration sensor. Diagram 1 shows this relationship in the simplest manner possible. The ServoTIG uses the APC (Automatic Penetration Control) function to determine the time of root penetration X.

Picture 6. Open Servo Weld head. Universal standard open weld heads (with or without cold welding additive material) suitable for all diameters of tubing in excess of 20 mm.

Picture 7. Mulyi ServoTIG Zappable for the benefit of 3 weld processes.

Picture 8. Thanks to the multilink system, if desired, you can start welding simultaneously at four different locations.

The root penetration sensor thus controls the entire orbital weld based on moment X. With the aid of WCC (Weld Cruise Control), if required, a skilled welder can also use his own experience to determine the time of root penetration X.
It also goes without saying that such a machine is not a cheap investment, however, in most cases, the rate of return will demonstrate that the purchase is justified. In any case, you can assume that cheaper machine operators are required instead of highly trained and skilled workers, thus allowing you to make considerable savings in wages. Moreover, when using such a digital welding machine, you can attain 50 to 500% of the output that was possible up to now. Everything depends on the working conditions because, for example, welding with additive metal requires additional visual checking.

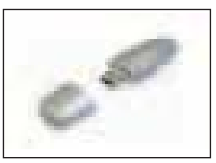
As a point of departure, you can assume that the production will be at least 50% higher, i.e. each operator is capable of attaining 50% more output. By using this technology, you can perform more orbital welds, and you will be more reluctant to revert back to welding by hand, thus attaining increased production.
You also save on the costs for materials, because material is not wasted by having to make test welds, or having to grind away or saw off faulty welds.
Moreover, since checking is no longer necessary, you also save on time, investments, storage and training related to checking equipment.
Since each weld is a production weld and since you can continuously change the tube diameter, you are able to make significant savings on logistical costs (walking /moving) in a plant. You can then work with all of the tube diameters to be welded from one corner of the plant to the other. Moreover, when deploying this welding machine on assembly projects in the field, the total construction time will be substantially reduced due to the higher production per operator. Shorter construction times provide the clients with a better return on the invested capital. Indeed, in many cases, it is possible to recover the purchase costs of the machine within the year.

Illustration 7 shows Mulyi ServoTIG Zappable for the benefit of 3 weld processe. As you build up more rows of cubes, you will be able to start welding at more locations simultaneously thanks to the multilink system that is thus created. It is even possible to start welding simultaneously at four different locations on the tube joint (as shown schematically in illustration 8). This enables the welding time to be reduced to 25%.
Illustration 9 shows the digital brain of the machine that is also housed in a cube. It is equipped with an extremely user-friendly graphical interface that enables you to easily input the diameter, wall thickness, type of material, starting position, etc., via a touch screen at the touch of your finger. After clamping the tube and applying the backing gas, the machine will do the rest in order to achieve a high-quality welded joint.

Checking

Because only certain persons are authorised to operate the machine, each welder has a personal key (see illustration 10) that he uses with a pin code to log on to the welding machine. At the end of the working day, ▶

Picture 9. The digital brain provided by a touch screen.



Picture 10. Dynamicc Key is a personal key for registration and storage for the welding logbook, management information and project welding management.

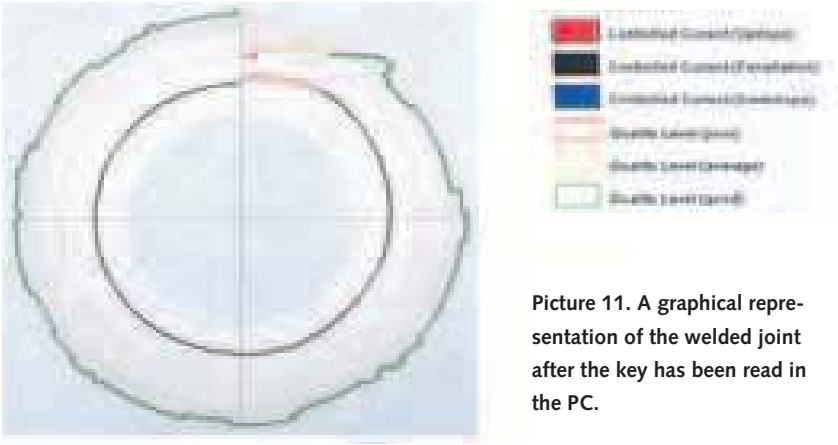
this key is handed in to, for example, the project leader who connects this key to the USB port of his PC. This provides the project leader with a comprehensive overview of the work performed by the welder and the quality because each weld can be represented graphically using Weldvision (illustration 11). This information can be saved in any desired way. In many cases, you can even omit additional expensive tests such as X-ray tests. Moreover, Weldvision also serves as a welding logbook so that separate logs do not have to be kept.

WCC

Another new concept is the WCC, the stands for 'Weld Cruise Control'. You can allow the orbital welding machine to operate, based on flow charts determined by the user. During the so-called 'up-slope' to the root penetration, you can then manually change the flow chart until the tradesman has determined that root penetration is optimal.
Thus in this case, you visually observe the root penetration and the WCC button illuminates when the machine has found the correct parameters. You can then use this WCC button to switch on the Weld Cruise Control so that the machine allows the desired root penetration to take place across the entire circumference of the tube. The settings found by the tradesman and the welding machine can be saved so that, if desired, they can be repeated in order to reproduce a constant welding quality. Upon completion of a WCC weld, Weldvision displays all of the data on the screen, as well as the listing of all measuring and control times and the welding logbook.

Database

After selecting Material (Werkstoff) number, diameter and wall thickness, you can save the root penetration that has been made (production weld, APC weld or WCC weld) with all machine and welding parameters, under a product or customer name or a unique number.



Picture 11. A graphical representation of the welded joint after the key has been read in the PC.

You can retrieve this saved program as often as you like in order to start welding processes. Moreover, even if you do not save this data, you can always make another APC weld or WCC weld in order to create and reproduce the optimal root penetration. After finishing a weld from the database, Weldvision also displays all of the data on the screen. In fact, Weldvision is the documentation, i.e. listing of the weld made based on all measured melting bath oscillations and controlled welding currents, including graphical representation, welding logbook, measuring and control times and management information.

Conclusion

Despite the futuristic concept of this unique digital ServoTIG welding machine, it is so user-friendly that even a child can perform the weld. Moreover, even inexperienced workers (i.e. laymen) can make optimal welded joints that provide a high degree of certainty that internal corrosion or the growth of all kinds of undesired substances and bacteria will not take place. Such welded joints thus not only provide a solution for the pharmaceutical and the dairy products sectors, but also for all other sectors where corrosive loading occurs on the inside of pipe networks. You can also perform optimal cleaning of pipe networks because, thanks to the ServoTIG, there are no high or raised internal welding beads that could obstruct the pigs.

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Also see website: www.dynamicc-welding.biz or phone (tel. +31 (0) 548 54 47 88). Questions can also be sent by e-mail to: nwbuijs@hetnet.nl.

About the author

Ko Buijs is a recognized metallurgical / corrosion specialist on stainless steels as well as special metals. He works for Van Leeuwen Stainless, www.vanleeuwenstainless.nl. In addition, Mr Buijs is a lecturer for various organisations such as steel associations, technical high schools and innovation centres. He has published over 100 papers in a number of technical magazines. In close co-operation with Barsukoff Software Mr Buijs has developed the computer programme Corrosion Wizard 2.0. Info www.corrosionwizard.com.