Practical information ab
of stainless steel

Great expertise is required in the processing of stainless steels to ensure sufficient quality of the joins and to guard against unexpected mishaps. This article offers advice about how to weld stainless steels and warns of the risks of welding it in an indiscriminate way.

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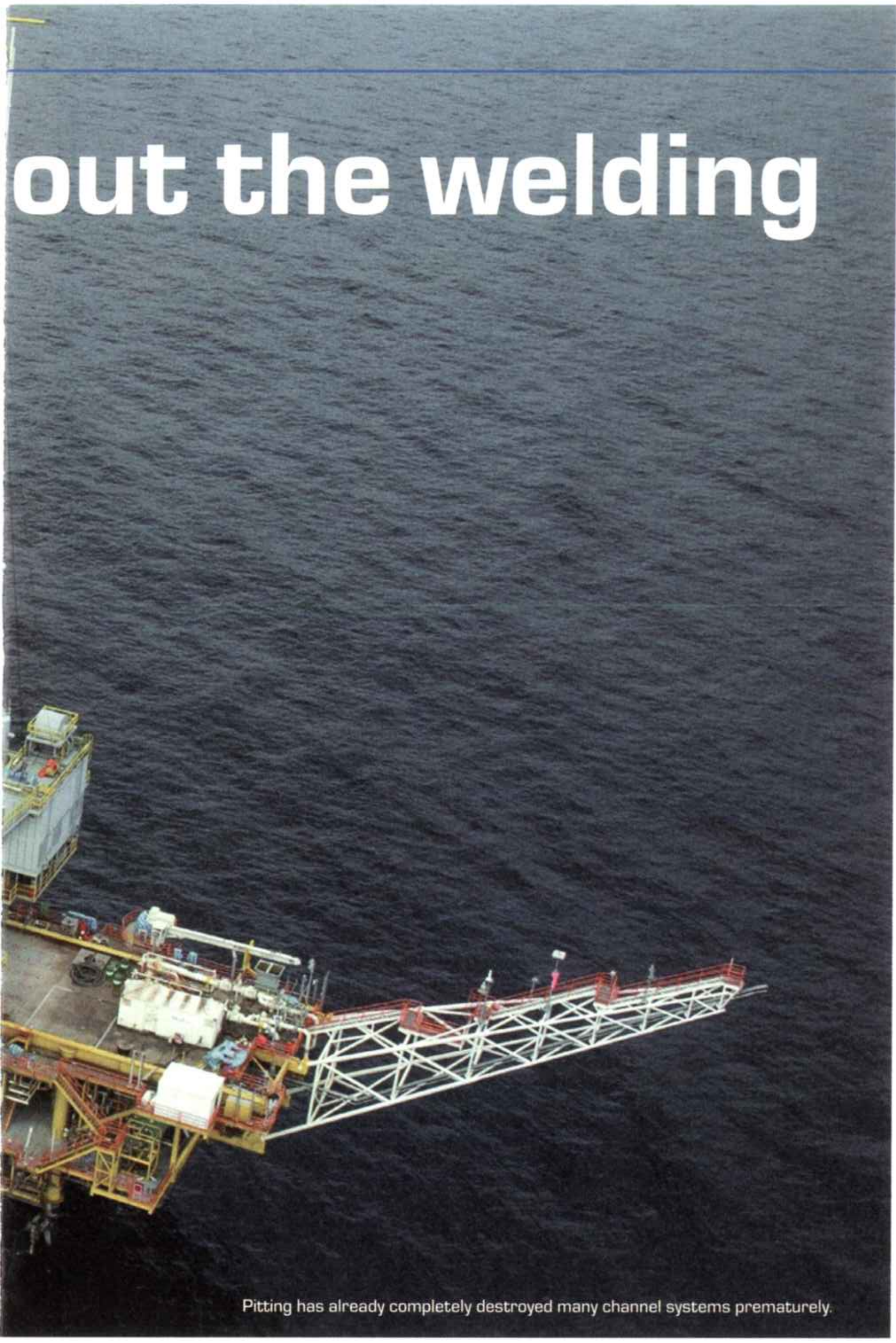
Stainless steel is an excellent material for welding, provided that the right rules are observed. It is important to realise that the weld or weld area is usually the weakest link in the chain. However, given the current state of welding technology and corrosion knowledge, there is no longer any reason why these weak links should occur. Inferior welded joints are often made through ignorance or laziness; joints are also made that later turn out to be sensitive to all sorts of corrosion mechanisms. Conversations with experts can prevent a lot of problems and corrosion damage.

Welding of stainless steel

In this article we will mostly be dealing with austenitic grades, since these are some of the commonest types used in welding. Because of their different physical properties, austenitic stainless steels are far less easy to weld than carbon steel. These differences have a considerable influence on the ultimate welding process. The linear coefficient of expansion, for example, is 1.5 times

out the welding



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higher than that of carbon steel, which means that after a thermal treatment a much higher stress remainder is left in the material. Tag welds have to be put much closer than with carbon steel. The inferior heat conduction capacity of austenite stainless steel causes worse heat discharges in the welded area. Because of this, welding in position is obstructed by slow coagulation. Intermetallic separations on the granule borders are more likely to occur because of the time factor. There is also the danger that the melting bath will overheat. The inferior conductivity can cause the feed electrode to overheat quicker. Because of these facts it is recommended to use the MIG welding process of electrode welding with thicker sheets because of the relatively low thermal stress. With thinner sheets (up to about 3mm) and pipes, the TIG welding process is usually recommended. With TIG welding the heat is obtained from an electrical arc between an infusible tungsten electrode and the workpiece. Because of this the TIG welding process is well suited to the welding of thin stainless steel and pipe joints, whatever the circumstance. Also, the TIG-welding process is often used for the placing of ground joints with thick sheets. Welding under dust cover is also applied in some cases.

When welding with stainless steel grades it is important that the preparation be optimal. Attention should especially be given to the cleaning and the pre-processing of areas that have to be welded. The welds should be dry, clean and especially grease-free. Grease and pencil marks contain carbon steel, which show a strong tendency to penetrate into the material, since the urge to absorb carbon steel is high during welding. Grease dissociates at high temperatures in carbon and hydrogen and it will be clear that this carbon steel will enormously corrode the weld quality (formation of chromium carbides). The joints ought to be flat and undamaged (free from burrs). The shape is dependent on the product that has to be welded.

As a general guideline, when welding stainless steel grades, any additional materials need to have, as much as possible, the same chemical composition as the parts that have to be welded.

It is possible to weld stainless steel both with coated electrodes and with welding wire (TIG/MIG welding process). Coated electrodes are used in hand welding. The advantages of hand-welding are that there is access to all the positions and that the heat supply is relatively low. Furthermore it can be carried out quickly, and at low cost. Also, the slag protects the back of the weld. One disadvantage of hand-welding is that slag rests, slag occlusions, spatters and start colours are likely to occur, so staining will always be necessary. The process also progresses quite slowly. Attention should be paid to the insulating cover of the electrodes, which has to be very dry.

With regard to wire joints (TIG and MIG), in general the advantages are that no slag or splatter forms, and the weld is well protected. With the MIG process the welding speed is high and the process is easily mechanized and automized. The disadvantages are that both processes are sensitive to wind (therefore operate inside) and that no correction of the weld bath is possible. Care should also be taken to obtain a good backing.

Corrosion

Many devices of stainless steel fail prematurely because of corrosion damage that has arisen through unprofessional welding. The additional weld material should always be the same as the basic material. In practice the types of corrosion damage presented here occur mostly as a result of incomplete welding. These forms of corrosion and the measures to prevent these as much as possible are discussed below.

Pitting

This form of corrosion is greatly feared, because a strong corrosion takes place merely locally. The stainless steels without molybdenum are the most sensitive to this form of corrosion. On average this form or corrosion shows up mainly where halogen ions appear, such as fluorine, iodine, bromine and especially chlorine ions. The cause of this corrosion can always be found in damage to or interruption of the passive layer of chromic oxide. An especially sensitive place where this corrosion appears is next to the weld join. Start colours are the evidence of this, because they indicate a strong local oxidation. This oxidation usually leads to a porous layer of oxide which allows the electrolyte to pass through. Especially the relatively small chlorine ion, which is necessary to keep the object passive, often penetrates deeper than the larger oxygen atom. It is therefore very important that similar start colours are removed with staining or polishing, possibly followed by another passivation. This staining happens mostly through a suitable pickle paste, because an immersion in a pickling bath is often not possible. In practice, it is often thought that everything is all right, but it is forgotten that the invisible insides can also have these start colours.

These kinds of problems appear regularly in pipe systems, even with the use of backing-gas. The reason is that there is still too much oxygen in the backing-gas and/or that the heavier backing-gas allows the lighter oxygen to stay high up in the pipe, where it will still start local oxidation. This form of corrosion has already completely destroyed many channel systems prematurely. Even conduits, through which for example, chloride-containing cooling water flows, can be completely full of leaks just next to the welded joints after one or two years.

Effective washing with backing-gas and the use of the right sealing tools will offer a good solution. Internal and external welding is also used simultaneously on the same spot, as a result of which the backing becomes superfluous. Normally a little hydrogen (about 2%) is added to the backing-gas in order to allow the oxygen to react with it, so that the stainless steel is spared.

However, in practice it often turns out that the hydrogen addition does not give the completely desired result. Helium can also be added to the backing-gas in order to chase away the oxygen at the top of the pipe. In order to make a good welding process the welding chamber must first be purged with formation gas according to the following formula:

$T=(4.10^{-6}.D^2.L)/F$

(T= purging time in minutes, D= diameter in mm, L = length backing room in mm, F = backing gas debit (rate of flow) in dm^3/minute).

It has also been shown that the flow rate must be fast enough that the total volume of the backing space is replaced about 20 times. This cannot be sufficiently emphasised, since experience teaches us that the quality of complete formation is far from satisfactory. It is only prudent to start the welding process if the amount of oxygen in the formation gas has decreased to less than 200ppm and, in critical cases, less than 50ppm. Slag rests can also further increase the risk of corrosion. Therefore these must always be thoroughly removed.

Stress corrosion cracking

Stresses often give rise to corrosion, therefore it is important that they be kept as low as possible. Stress areas in an electrochemical system are always anodic and similar spots sacrifice themselves on behalf of the cathode, which usually has a surface many times bigger: this accelerates the corrosion process even more. The phenomenon which arises is the transcrystalline corrosion, which means that the corrosion propagates across the metal crystals.

Small micro-cracks on the surface cause a rise in stress in that specific area, which becomes anodic and corrodes. During corrosion the hydrogen ion takes an electron from the electrolyte of the ion metal which has come into the solution, so that hydrogen forms. This hydrogen diffuses locally into the surface of the stainless steel, which leads to local embrittlement. This cause the small seam to propagate easily, as a result of which the transcrystalline crack can form quite quickly. This serious corrosion generally appears only with halogen ions such as chloride.

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In order to prevent stresses in stainless steel as much as possible, it is advised to weld the parts as much as possible in a cold state with the current density as low as possible and the weld speed as high as possible. Care should be taken that the welds are not laid too close to each other and that the welds do not cross each other. Tag welds must therefore be made as small as possible; therefore the use of attach strips is never recommended. Since, because of shrinking, the welds also cause extra stress, it should be ensured that these welds have a minimum content, without this happening at the expense of the strength of the connection. In practice annealing should be done at 1060°C.

Intercrystalline corrosion

Chromium carbides can eventually form on the granular borders at a short distance from the weld under the influence of the heat. This is visible in the TTT (Time, Transformation and Temperature) diagram. The diagram shows that these undesired carbides can form if the carbon content, temperature and time allow. In other words a stainless steel containing less carbon will be much less sensitive to it than the kinds with a higher content of carbon. Empirically, it has been found that the chromium carbides arise on the granule borders only if the carbon content is higher than 0.04 %. In practice, thin-walled stainless steel does not generally suffer from this phenomenon because the cooling time is short owing to the thinness of the plate.

In this last case, therefore, there is not enough time for these carbides to form. These carbides form especially in the temperature range between 550 and 900°C. At a certain distance from the weld there will be a "sensitive" area that allows these carbides to arise. Therefore there is always corrosion at a certain distance from the weld and not immediately next to the weld, such as has been the case with the "knife-line attack". These carbides arise on the granule borders because it is there that the tendency for similar links to arise is highest. Corrosion can even reach such serious forms that the granules become loose from each other. These precipitates withdraw chromium from their environment and through this the environment is baser than the rest. The environment of the carbides thus becomes active and will quickly corrode to a great extent. If there are also stresses the corrosion is further intensified. Weld decay is also a form of intercrystalline corrosion.

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. 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