Risks with the welding of stainless steel (3)

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Welding stainless steel is not without risk at least when this work is performed with insufficient knowledge. In the two preceding articles (MK6 and MK7) the metallurgical aspects and the damage from corrosion as a consequence of unprofessional welding were highlighted. This last article of the series concentrates on heat cracks as a consequence of welding and gives a summarized overview of certain welding aspects.

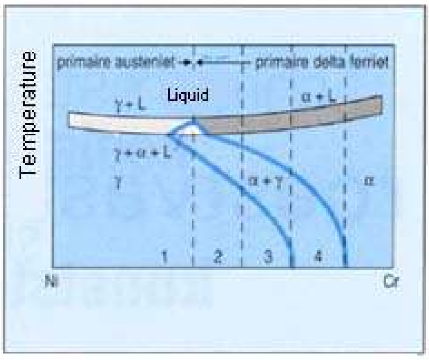
Even if stainless steel is a material which can be welded very easily, certain rules should be followed in order to avoid later formation of corrosion. Besides these, other problems can arise with austenitic stainless steels when welding is done without enough knowledge, namely the origination of heat cracks.

Heat cracks
Austenitic stainless steels can be sensitive to the so called heat crack effect (picture 19). Heat cracks are usually caused by eutectic alloys which already melt at lower temperatures (for example 1000°C). This effect arises mainly when stainless steel solidifies primary austenitic from the melting zone. Austenitic stainless steel will solidify primary ferritic and austenitic depending on the chrome and nickel content (picture 20). If it solidifies primary ferritic then an almost complete austenitic structure will arise through segregation and transformation. If it solidifies primary austenitic, at the same time an austenitic matrix will arise with a resting smelt of a little ferrite.
In picture 20 it is also visible how the so called duplex qualities originate. These facts have a big influence on welding and on the sensitiveness to heat cracks. If the stainless steel solidifies primary ferritic, the chance of having heat cracks is very small, unless the correct welding parameters are observed. When stainless steel solidifies primary austenitic everything should be done in order to avoid heat cracks. Amongst other things this can be done through:

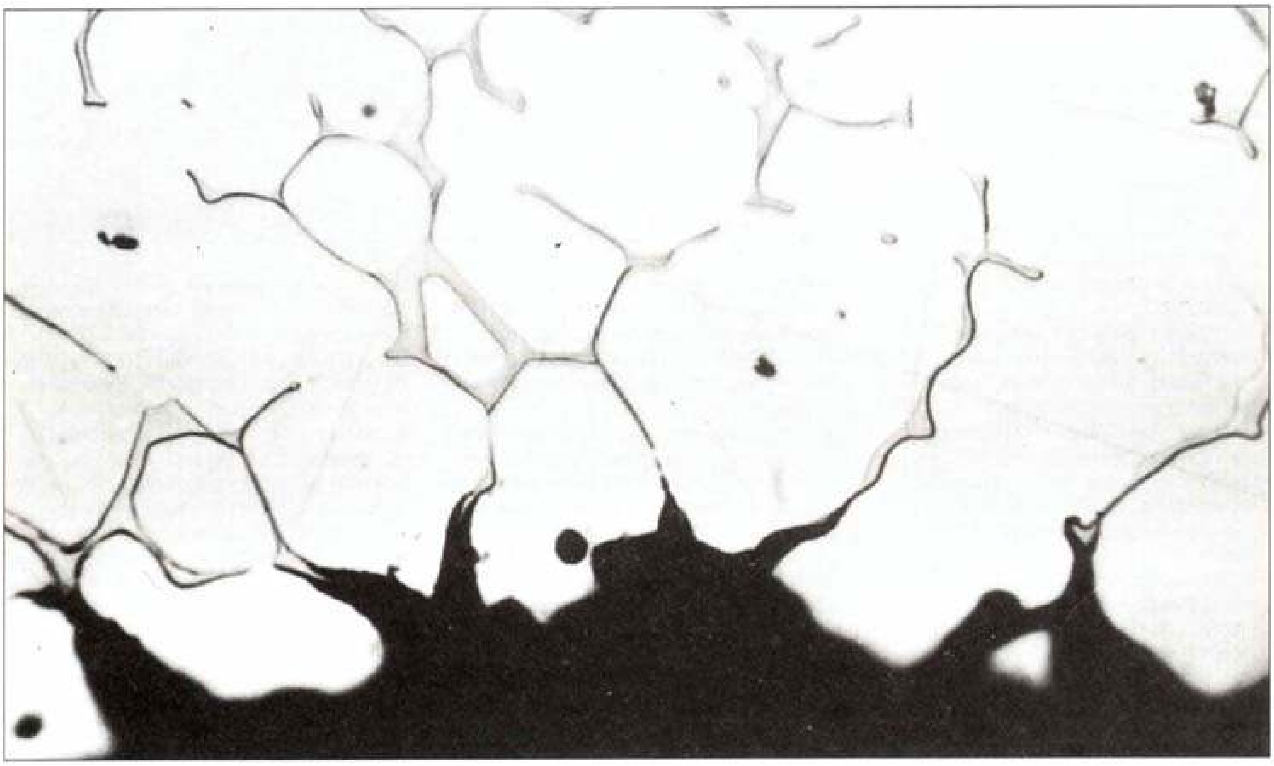
- a good alloy with the mother material
- very pure welding additive materials which possibly contain a little molybdenum and manganese
- no big welding caterpillars
- maximum heat contribution (+/- 1.5 kJ mm).

The reason for which primary ferrite solidified qualities are less sensitive to heat cracks is because ferrite has a much higher solubility towards various elements than austenite.

Heatcrack in welding metal



Schematical pseudobinar diagram for 70% Fe in Fe-Cr-Ni alloys (according to Lippold and Savage

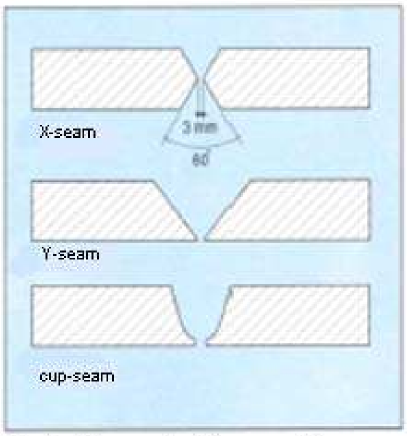


21. Preferential attack of ferrite

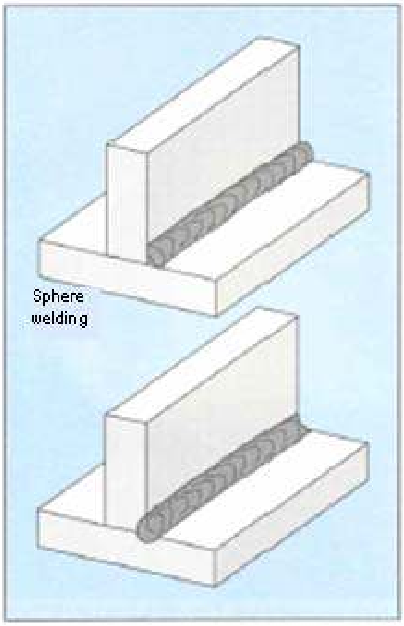
Primary solidified ferritic stainless steel
All these stainless steel qualities are chilled from about 1050°C, and this makes that the structure which is than almost completely austenitic, is frozen in. If, after this process, the material is being welded, it is clear that the suppressed ferrite is being separated in the welding transition. This will give an excellent welding alloy, as long as the ferrite is tolerated. In practice it is shown that this last mentioned fact usually does not cause any difficulties, even if sometimes there are specific cases of preferred corrosion of ferrite as can be seen in picture 21. However, this magnetic ferrite can be a problem when the magnetic permeability needs to be low, like in certain measuring instruments, think for example of the compass rooms. In conclusion, it can be said that primary solidified stainless steel types can be welded without any problem without heat cracks.

Primary solidified austenitic stainless steel
As shown in picture 20, these qualities have a higher nickel content. For this reason certain problems and consequences can be caused, like:

- a complete austenitic structure from the melting till the room temperature; the consequence for this is that little undesired elements can be 'imprisoned' which are typically those which cause heat cracks (table 7). For this reason it is clear that these types are even more subject to heat cracks;
- due to lack of ferrite the elasticity and the notch toughness will be increased and the stretch border will decrease. This can be partly compensated by adding 0.1 till 0.2 % of nitrogen. The notch toughness at low temperatures is better than in the primary ferritic coagulated types;
- the magnetic permeability is low (<-1.001) which is extremely pleasant for certain types of application;
- in order to reduce the tendency to heat cracks, it is advisable to take an austenitic welding additive material with low ferrite content. This ferrite can absorb much better the undesired elements as a 'trashcan'. What should be made sure is whether this ferrite is allowed in connection with the magnetism which will arise locally;
- the bigger the welding caterpillar, the bigger the risk of sensitiveness to heat cracks. Therefore, the welding additive material has to be extremely pure. Small increases of molybdenum and manganese content is therefore usually a must.



22. The X-seam, the Y-seam and the cup-seam each have their specific applications



23. During welding electrical potential is important

Summary

Summarizing, the problems which can arise while welding stainless steel can be divided in two categories, the problems at processing a thin-walled material and those when processing a thick-walled material. The thicker the walls get the more the problems will increase, for which reason the preventive actions need to be sharpened.
The problems which can arise earlier with thickwalled materials than with thin walled materials are:
- secretion of friable intermetallic alloys;
- a control of ferrite content;
- heat cracks, and this mainly when using primary coagulated austenitic stainless steel;
- welding of various densities;
- the choice which should be made in relation to the correct preheat- and low-stress glow temperature;
- to obtain the correct hardness
As to thin-walled stainless steel the problems can be of a total different nature, like:
- control of the ferrite content (this plays a big role with duplex qualities);
- making good cross welds;
- undesired transformations;
- applying the correct backinggas and checking on the present oxygen
The importance of 'backing' correctly is usually underestimated, because people think to be working without oxygen while usually this is not the case. The tendency of the lighter oxygen to drift mainly on the backing gas, has persuaded apparatus builders and installators when welding pipe joints to have the pipe spinning, so that the weld torch can always firmly stay placed in the lowest position. Naturally this is not realizable in all situations. The so called 'tandem'-welding is also gaining more and more interest. In this case, a weld is put on both sides at the same time, this makes 'backing' superfluous. This method requires an accurate and professional guidance, because little differences in distance of the weld torches can lead to undesired oxidations. For thicker plates it is better to use an X-weld-juncture , because in this way a symmetric filling is obtained and a smooth shrinkage, which will conduct to a minimum deformation. Also the juncture content is smaller, whereby the thermal load is smaller than with a V juncture. As general rule X-junctures are never used when the plate thickness is more than 30 mm (pict. 22). As to corner welding it can be noticed that similar welds are often underestimated as to their difficulty degree. The weld juncture should be carried out in such a way that there is a positive burning in and that the sides are well merged. It also regularly happens that the suture welds are wrongly set, or the stream strength is too high whereby cracks originate in the joint weld, or the stream strength is too low whereby no positive burning is obtained. The nob and the crater always need to be polished off in order to prevent binding errors and/or snail encircling. Also when completing welding the setting of the correct stream density is very important, because with a too low stream density a spherical weld will originate (picture 23). If the streamstrength is too high, the risk of having cracks is very high.
The best thing is to keep the weld electrode under 45° and in the length under 80°. Naturally, there is much more which can be said about welding of stainless steel. The information provided in this article, however, covers a lot of elementary information which on itself 'deserve' a publication. For this reason it is important to discuss with the supplier of weld additive materials, but also with the supplier of weld materials, to come to a perfect choice, in order to reduce the risk of errors to a minimum. One thing is sure and that is that a lot of corrosion damage has arisen due to erroneous or defective welding.

Table 7: Maximum solvability of different elements in a ferritic and austenitic structure

	ferrite		austenit	
element	%	Temperature (°C)	%	Temperature (°C)
Si	18,5	1200	2,15	1170
Nb	4,5	1360	2,00	1220
P	2,8	1050	0,25	1150
S	0,18	1365	0,05	1356

Responsibility

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Literature

- Characteristics and properties of stainless steel (part 1,2 and 3); eng. N.W.Buijs – Metal and plastic , year 1993, nr. 2,3 and 4;
- Corrosion: origination and prevention (part 1 and 2); metal and plastic year 1992, nr. 6 and 7.

GTAW welding of a stainless steel tube