Marine Corrosion Forum and Institute of Corrosion partnering with

Roger Francis
RF Materials

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“Improving the Corrosion Resistance of Duplex Stainless Steel Welds”
About Me

Dr Roger Francis is one of the UK’s leading experts in corrosion resistant alloys – both stainless steels and copper-based. Director at RFMaterials, Dr Francis won’t mind us telling you that he has amassed four decades (and counting) of experience in areas that include marine, oil & gas, chemical & process, power, desalination, and mining.

He has authored 6 books, and edited several more, as well as publishing over 80 technical papers. His consultancy work includes failure analysis, materials advice, and training in various aspects of corrosion. A founder member of the Marine Corrosion Forum and a Fellow of the Institute of Corrosion, Roger never fails to deliver an informative and enjoyable paper.
Q&A

Selection of Questions to Roger Francis, Post-Presentation 06/07/2020
Questions and Answers – MCF / ICorr Joint Event
July 2020

• Q. What is the recommended duration of the G48 test when qualifying a WPS?
  • A. 24 hours. It is written into NORSOK and it is what I have used in the 30 years I have been dealing with duplex stainless steels. It is also the duration of the test that has been written into ISO17781. The general consensus is that 24 hrs in a G48 test, is long enough to identify if the weld is good or not.

• Q. Post Weld Cleaning....this can still be a problem with Field Joints, that can not easily be Treated prior to service?
  • A. If you are doing field joints it can be difficult, you can wire brush or pickle the outside but if the root is exposed then probably the best thing to use is to use nitrogen containing weld gases and qualify an argon 2,3, 4 or 5% nitrogen mix. I have been involved with production fabrication in the ME, where we have had to resort to using argon nitrogen gases and it has been very successful.

• Q. If a specification requiring super duplex to pass G48A at 40 °C, what can be done to achieve that?
  • A. You need to pickle the welds, and that means if you are going to pickle the PQR and then you will have to pickle the in-service welds and I would also recommend argon-nitrogen welding gases to make sure the weld is as good as possible.
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• Q. Is it a must to add Nitrogen on welding gas to achieve the 40 °C?
  • A. yes, I have been involved in a project where this was required and we added nitrogen to the gas and passed the G48 test at 40 °C.

• Q. Generally we get requirements where microstructure of the weld shall be free from intermetallic phases, especially sigma phase (total maximum content of 0.05%). What is your take on the maximum allowable percentage?
  • A. If you do all 3 tests and you pass the impact toughness test and a corrosion test, there may be a bit of sigma there, but it is not affecting the performance of the weld. Putting a percentage on the sigma phase is difficult as it is the particle diameter which is critical as to how much it reduces the corrosion resistance.
  • If you go from a 2 micron to a 4 micron particle diameter you move the threshold from 4% to 1%, as it goes by the square of the particle diameter. So bigger particles have bigger reductions in resistance, but it is possible to get fine particles, where you could tolerate even more than 4%. Trevor Gooch demonstrated this many years ago that if you get small fine particles of sigma, which you can see at high magnification, but they had no impact on corrosion resistance. Therefore it is down to particle size, this is why just looking at sigma particles and counting them doesn’t tell you much about corrosion resistance. Do the quality control tests as they are much more reliable.
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• Q. After welding, what are the recommended post heat treatments of welded alloys to recover the original microstructure? for example 2205
  • A. It depends what is wrong with it. If it is just sigma precipitation then you have to heat it hot enough and long enough to dissolve the sigma phase and produce a reasonably homogenous microstructure. This mean it will have to be solution annealed at 1050-1100 C (for 2205) depending on the thickness of the weld, for long enough to re-dissolve the sigma phase and enable some diffusion away. It wouldn’t necessarily be a long heat treatment unless it was a thick section, but it is tricky and it is rarely done. Its more common to cut out the weld and start again, if necessary putting a piece of pipe in and having 2 welds but getting it right the second time around.

• Q. ISO 17781 is recommending -46°C for impact testing. I see you are still recommending -50C. What are your thoughts on this?
  • A. -46°C is the result of a conversion from Fahrenheit to Celsius. Therefore, when we wrote the tests for welds at Weir, we decided to use a round number in metric, hence the -50 °C. If you want to use -46°C the 4 °C is not going to make any difference.
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• Q. Is NORSOK still considered to be a very relevant document for Duplex?
  • A. The ISO17781 has largely superseded NORSOK in terms of testing as it has detailed descriptions of how to test all grades of duplex Stainless steel for satisfactory microstructure and it also has details on how to test welds under various conditions.
  • ISO has probably superseded NORSOK in terms of welds, and I don’t know if NORSOK has any plans for re-issuing, but there are a lot of NORSOK people who sat on the ISO17781 committee.

• Q. What should be the minimum distance between two adjacent joints in a pipe??
  • A. That depends on the grade and the thickness, you need to refer to manufacturers recommendations. The root gap spacing does vary depending on the thickness, the manufacturers know their product better than anyone and you should refer to their recommendations. The IMOCA document may also refer to root gaps before welding, but I cannot be certain. For the spacing between adjacent pipe welds I would recommend at least 50mm and preferably more.
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• Q. Do you have rough data about convenience in High pressure oil and gas facility to make flowline and pipeline in Superduplex SS instead of more "traditional" CS + cladding in 625?
  
  • A. You have to consider the internal environments. If we are talking about sour then it has to be ISO 15156. We can step outside the limits for super duplex as the standard allows you do so this if you have adequate data. But you also have to look at cost and fabrication. i.e. Where is it going to be fabricated? if this is going to be in say a European or North American yard where there is lots of experience with fabrication of clad pipe then this is fine. If you are doing it on site in a remote area, it is much more tricky welding clad pipe than a super duplex. But you still need to be skilled to weld super duplex. You need to look at all these elements to work out what is going to give you the best chance of achieving good quality welds at an affordable price. Every project is different.

• Q. Can you please suggest any precautions to be taken before put in service, if preferred microstructure is restored/ sigma phase particle removed using heat treatments .
  
  • A. If you detect sigma phase in the parent metal, send it back it is not fit for purpose. If sigma is in the weld you are going to have to perform some form of solution anneal for long enough to dissolve the phases and also to allow diffusion to get some homogeneity so you don’t have concentrations of chromium and molybdenum. After heat treatment you will need to remove heat treatment scale by pickling.
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• Q. When welding super martensitic stainless steels, they are usually welded with a Zeron 100 root and a fill of 2205. what is the reason for this?
  • A. If you weld martensitic alloys with martensitic fillers then you have to post weld heat treat which is very difficult. You are welding the root with something with good corrosion resistance. If you are going to fill it with 2205, maybe 2205 doesn’t have adequate corrosion resistance so by putting the root in super duplex you get that good corrosion resistance at the weld root. I know martensitic piping has been welded with 100% super duplex filler and I guess its just a way of saving money by using super duplex for the root and 2205 for the filler. Alloy 2205 is not as strong as superduplex so the desired strength must also be taken into account.

• Q. An operator in the UK North Sea insists on 2G and 5G PQR's for welding in all positions for a WPS for 22Cr and 25Cr Duplex, and won't accept 6G PQR in lieu. 6G is however accepted for Carbon Steel for all positional welding. Why is duplex treated differently for PQR qualification welding position i.e why 2G and 5G rather than 6G??
  • A. I have no idea, as welding positions have no effect on the corrosion resistance. You need to speak to a welding engineer to get an answer to that. Providing you do all the adequate testing of the PQR you will know if it is fit for purpose or not.
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• Q. Post heat treatment, to do solution treated, but what about after that step; should be quenched, or can be air cooled also.
  • A. Only in very thin sections can air cooling be used. I know Sandvik have used air cooling on very thin section heat exchanger tubing, but you will never get fast enough air cooling on a 6 or 10 mm thick pipe; it has to be water quenched pretty fast. It has to get to the tank within 60 seconds and be fully submerged; the tank has to be big enough to reduce the temperature quickly. I have published papers on this and I would never go for air cooling on duplex and super duplex as you cannot get cooling fast enough unless on thin sections i.e. 1mm or 2mm at a push.

• Q. What's the competitive advantage of Duplex alloys over 254 SMOs. Which is relatively easier to weld and meet the typical offshore requirements?
  • A. Super duplex is, as you are going to weld 6% molybdenum alloys with a high nickel alloy filler; usually alloy 625 nickel-chrome-molybdenum alloy. For some applications you may have to step up to a higher alloy like C-22 or alloy 59, but all of these are nickel based alloys so the weld pool is sticky and doesn’t flow like an over alloyed super duplex filler does. It is far easier to weld super duplex than 6% molybdenum alloys.
Q. Are there any chances of distortion of Super duplex SS because of PWHT like 300 series SS?

A. Yes there are. This is why when you have problems like this PWHT is probably going to lead to distortion and this may not be acceptable. The one exception to this is castings. With casting, providing you haven’t done the final machining, but you have done the rough machining and tested it and found defects and then done weld repair, PWHT is feasible and quite common. If it is anything other than a minor weld repair you will have to do PWHT as this won’t introduce much distortion in something like a pump or valve body. There will be some distortion but you will be able to final machine it back to the specified tolerance. If it is something like a thin wall pipe joint then it will significantly distort.