Good welding practice Stainless Steels

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Stainless Steels

- Four basic types of stainless steels,
  - Austenitic, most common
  - Ferritic
  - Martensitic
  - Duplex, main use oil & gas
- with different properties and hence different applications:

- All are weldable but with different problems.

Typical Stainless applications

- Austenitic – process plants, cryogenics, medium corrosive applications, used over wide temperature range
- Ferritic – low cost variant, bulk handling equipment, road/rail vehicles, not for elevated temperatures (<300°C)
- Martensitic- high strength/high hardness, aerospace, medical, petrochemical
- Duplex- oil & gas extraction/production, not for elevated temperatures (<300°C)

Arc Welding Processes

- ARC WELDING
  - MANUAL METALLIC ARC — MMA (SMAW)
  - TUNGSTEN ARC INERT GAS SHIELDED — TIG (GTAW)
  - METALLIC ARC ACTIVE GAS SHIELDED — MAG (GMAW)
  - FLUX CORED ARC WELDING — FCAW
  - SUBMERGED ARC WELDING — SAW
  - PLASMA ARC WELDING — PAW
  - ELECTRON BEAM WELDING — EBW
  - LASER BEAM WELDING — LBW

- SOLID PHASE WELDING
  - FRICTION WELDING — FW
  - FRICTION STIR WELDING — FSW

Austenitic stainless steels

Austenitic stainless steels

- Welding problems
  - Weld metal solidification cracking
    - More likely in fully austenitic structures.
    - Mainly Sulphur & Phophorus.
    - The presence of 5-10% ferrite in the microstructure is extremely beneficial,
    - The beneficial effect of ferrite has been attributed largely to its higher solubility of harmful impurities.
  - Welding Consumables
    - usually matching filler metals
    - The choice of filler material composition is crucial e.g. when welding Type 304 stainless steel, a Type 308 filler material which has a slightly different alloy content, is used.
    - Weld metal composition can be predicted from the Schaeffler diagram

Austenitic stainless steels

- Welding problems
  - Welding Consumables
    - The choice of filler material composition is crucial.
    - Filler choice depends on required mechanical and corrosion properties – often higher alloy (nominally matching)
    - Autogenous welds are possible, but usually welded with matching filler or slightly overalloyed.
    - e.g. when welding Type 304 stainless steel, a Type 308 filler material is used, which has a higher alloy content, to promote some ferrite.
    - Weld metal composition can be predicted from the Schaeffler diagram

Austenitic stainless steels

Schaeffler diagram

Stainless steel composition predicts whether solidification is initially ferrite (δ), austenite (γ), or a mixture (δ+ γ)

Austenite stabilisers, Ni_{eq}

- Carbon, Nickel, Nitrogen, Manganese, Copper

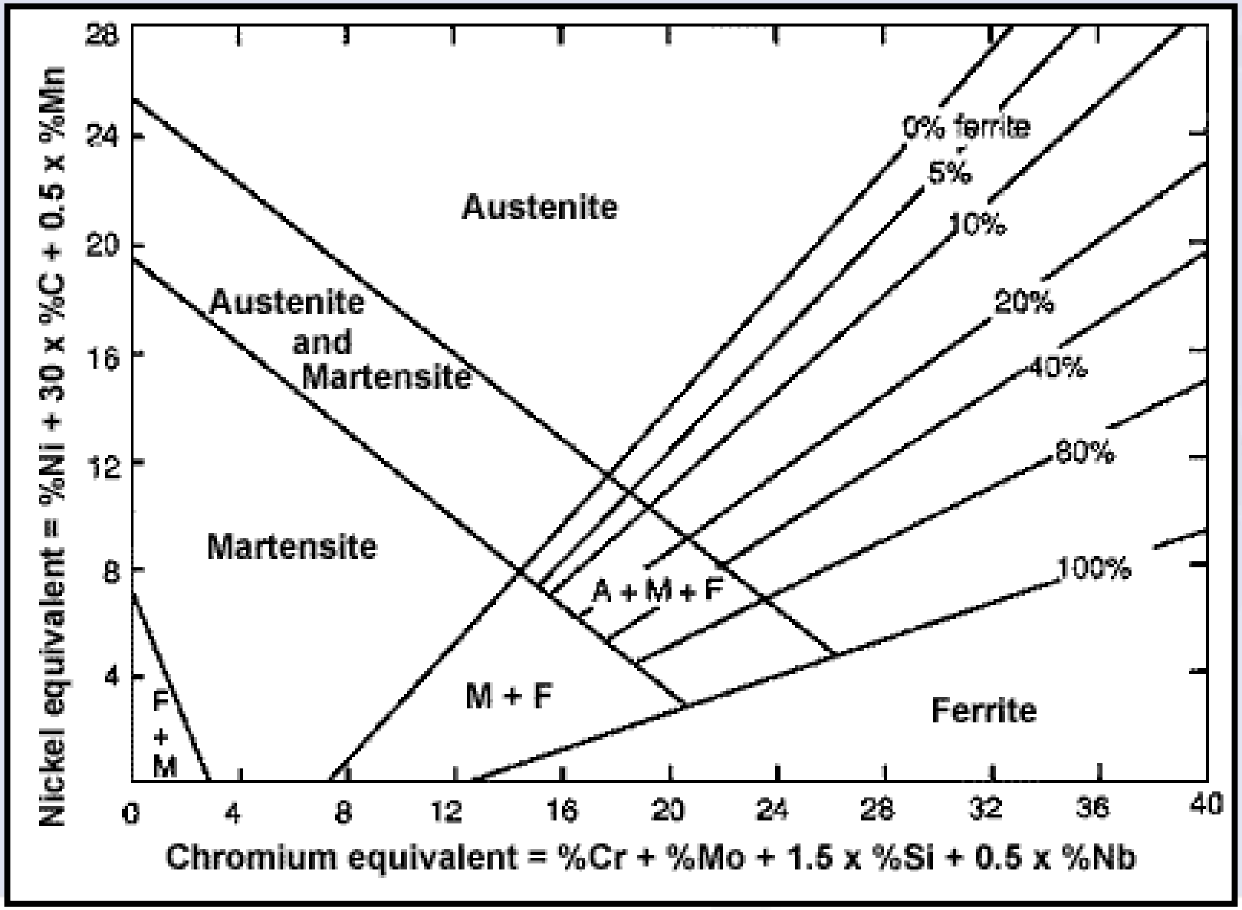
Ferrite stabilisers, Cr_{eq}

- Chromium, Molybdenum, Tungsten, Niobium, Silicon

Modifications to this diagram include DeLong diagram and WRC diagram

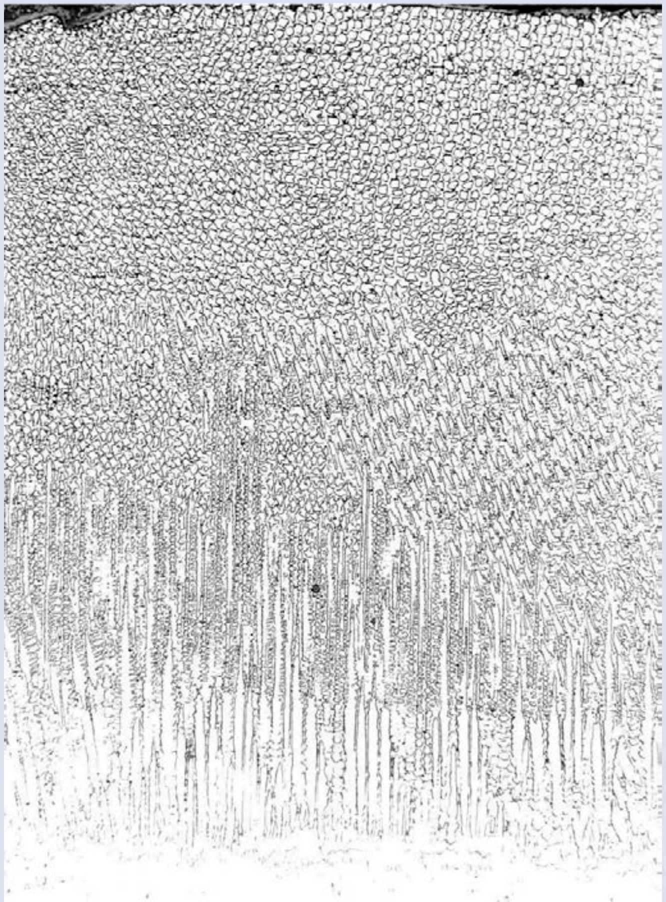
Austenitic stainless steels

- Schaeffler diagram predicts weld metal phases

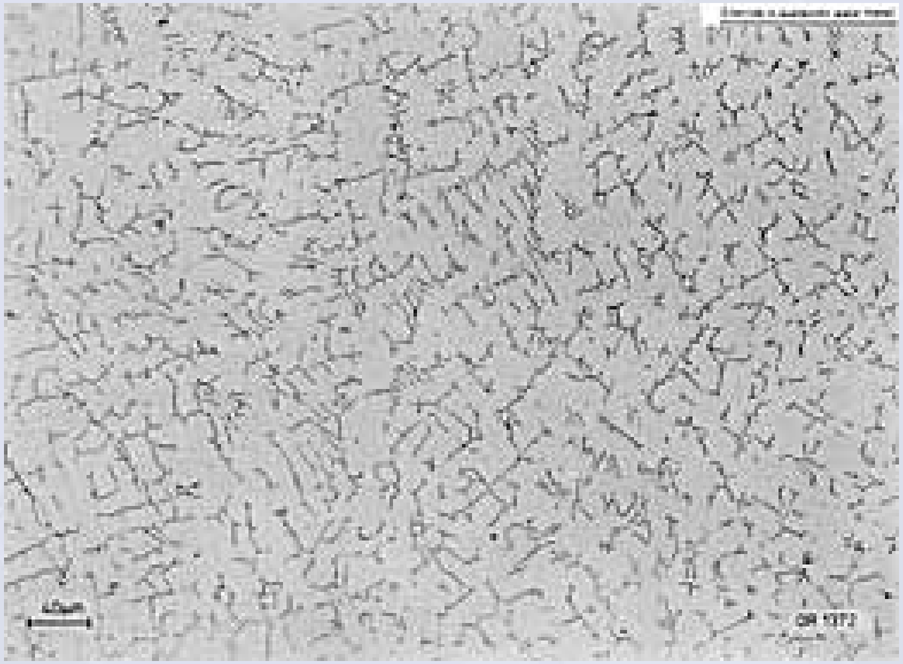


Weld microstructure

- Weld bead



- Delta ferrite (dark regions)



Austenitic stainless steels

- Welding problems
  - Distortion
    - Low Thermal conductivity
      - 15 W/m°C compared to 47 W/m°C for Csteel
    - High Coefficient of Expansion
      - 16 µm/m°C compared to 10 µm/m°C for Csteel
  - Minimise
    - Limit weld volume
    - Accurate fit up: avoid wide gaps and misaligned edges
    - Maintain low interpass temperature (~150°C max).
    - Avoid high heat input techniques i.e. large weave, high welding current, slow travel speed

Austenitic stainless steels

- Other issues:
  - Weld cold:
    - No preheat required, as cold cracking not an issue.
      - Austenite solubility of H_2 is 8x that of Ferrite
      - Rutile electrodes are acceptable
  - Avoid Post-weld heat treatment,
    - not normally required
    - risk of precipitation and sensitisation, 550 - 800°C
  - Avoid non-removable backing rings
    - risk of crevice corrosion

Ferritic stainless steels

Ferritic stainless steels

- Sensitive to grain growth
  - loss of toughness, embrittlement
  - limited to 250°C service temperature
  - can lead to cracking in weld or HAZ of highly restrained joints and thick section material.
- Hydrogen cracking
  - Can suffer cold cracking similar to Carbon Steels.
- Filler metals:
  - matching, austenitic or nickel alloy

Ferritic stainless steels

- Usually parent materials are thin plates or tubes.
- Austenitic Fillers
  - When welding thin section material, (< 6mm) use an austenitic filler and no special precautions are necessary.
  - In thicker material, if using an austenitic filler to produce a tougher weld metal, it is necessary to employ a low heat input and max interpass of 150 °C to minimise the width of the grain coarsened zone.
- Nickel Fillers
  - Used if PWHT required

Ferritic stainless steels

- Matching Fillers
  - If welded with matching filler, preheat and PWHT (due to hard martensitic formation). Preheating will reduce the HAZ cooling rate, maintain the weld metal above the ductile-brittle transition temperature and may reduce residual stresses. Preheat temperature should be within the range 50-250 °C depending on material composition.

Martensitic stainless steels

Martensitic stainless steels

- Welding Problems
  - Hydrogen cracking
    - Normally matching consumables.
    - High hardness in the HAZ makes this type of stainless steel very prone to hydrogen cracking above >3mm. The risk of cracking increasing with the carbon content.
    - Take precautions to minimise hydrogen

Martensitic stainless steels

- Precautions which must be taken to minimise the risk, include:
  - using low hydrogen processes
  - preheating to around 200 to 300 deg.C.
  - maintaining the recommended minimum interpass temperature.
  - Allow cooling to ambient to ensure complete transformation to martensite prior to PWHT
  - carrying out post-weld heat treatment, e.g. at 650-750 deg.C.

Duplex stainless steels

Duplex stainless steels

- Preheat is not normally required.
- Heat input and the maximum interpass temperature must be controlled.
  - Too high cooling rate produces high Ferrite
  - Too slow cooling rate precipitates third phases
- Choice of filler
  - critical to produce a weld metal structure with a ferrite-austenite balance to match the parent metal.
  - To compensate for nitrogen loss, the filler may be overalloyed with nitrogen or the shielding gas itself may contain a small amount of nitrogen.
- Complex !

Welding Stainless steels to Carbon/Low alloy steels

Stainless to Low alloy steels

- Austenitic Stainless
- Welding Problems
  - Dilution of weld metal from the Low alloy base material .
  - possible formation of hard brittle structures,
  - use an overalloyed austenitic stainless filler material type 309 (24% Cr 12% Ni), weld deposit will be ductile-can tolerate high dilution from carbon steel/low alloy steel
  - pre-heat is not usually required
  - Upto 15% ferrite to avoid hot cracking
  - Not suitable for PWHT or above 400°C due sigma phase

Stainless to Low alloy steels

- Austenitic Stainless
- Welding Problems

  Alternative Ni-based consumables (ENiCrFe-2 and ENiCrFe-3, Alloy 600 type)

  – PWHT still a problem for the SS

    - Recommended fabrication sequence

    1. Butter the ferritic steel with Ni-base consumables
    2. Apply the PWHT to ferritic steel+buttering
    3. Complete the joint with Ni-based consumables

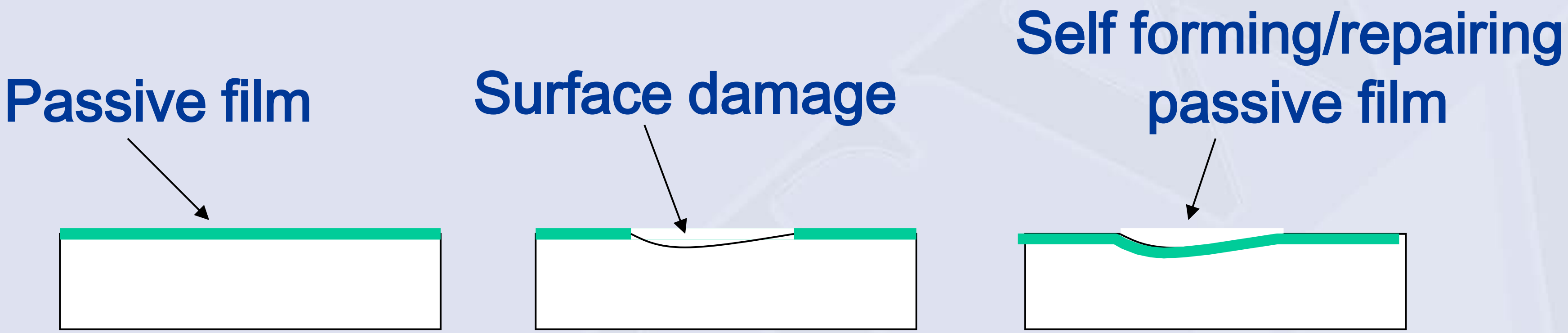
Stainless to Low alloy steels

- OTHER STAINLESS GRADES
  - Use above consumables or consumables matching stainless grade, with same precautions, dependent on the application.

Cross contamination

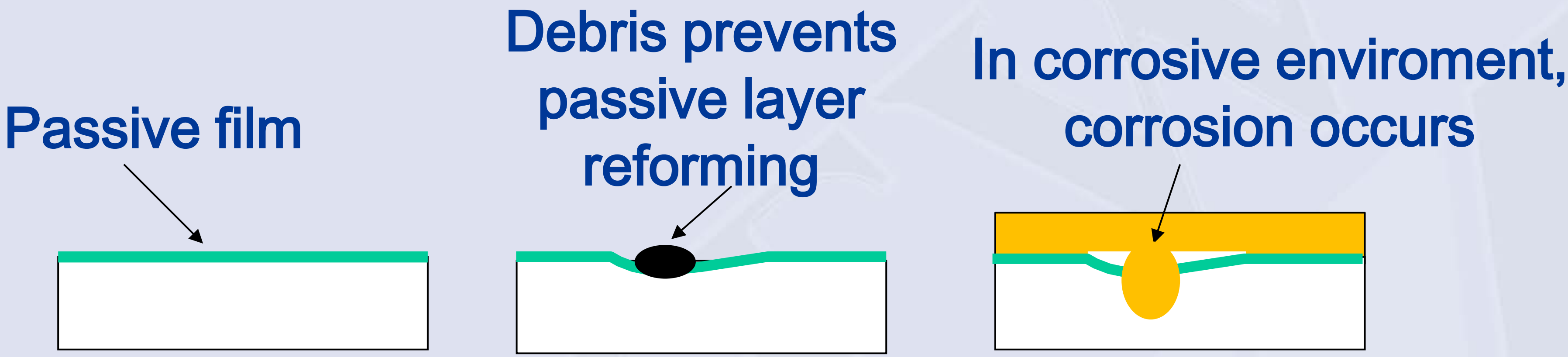
Cross contamination

- A steel that contains at least 10.5% chromium.
- Forms a Cr oxide coherent passive layer (protective film), which is approx 10 micron thick.
- This is normally self repairing in air.



Cross contamination

- If damaged with non corrosion resistant material.
- Passive layer is prevented from reforming
- This can then lead to corrosion of stainless in a corrosive enviroment.



Cross contamination

- Prevent carry over of particulate contamination
  - consider forming processes
    - Rolls, pressbrakes and guillotines
  - use tools dedicated for use on stainless steel
    - use INOX grinding discs, SS wire brushes
    - avoid contact with steel chains, forks, benches and hammers
    - avoid walking on stainless steel material
- Other considerations
    - Use chloride free marker pens, tapes etc

Cross contamination

- Fabrication.
  - Clean joint and adjacent parent material to remove dirt, grease, oil, paint and sources of moisture
  - temporary attachments materials should be compatible with the parent material
  - Arc strikes can act as initiation points for pitting corrosion and cracks
  - Appropriate post-weld cleaning to obtain good corrosion resistance , remove spatter, slag, arc strikes, oxides (discolouration) around weld.
  - Pickle and passivate if required to restore protection.