Spoilt for choice: what grade selection means for fabrication parameters

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Scope of the presentation

- About Euro Inox
- Grade selection process – when and why
- Heat treatment in fabrication
  - Solution annealing
  - Annealing
  - Quench hardening
  - Stress relieving
- Pickling and passivation

Euro Inox

Members:

- Integrated European producers of stainless steel flat products
- National associations
- Alloying element organisations

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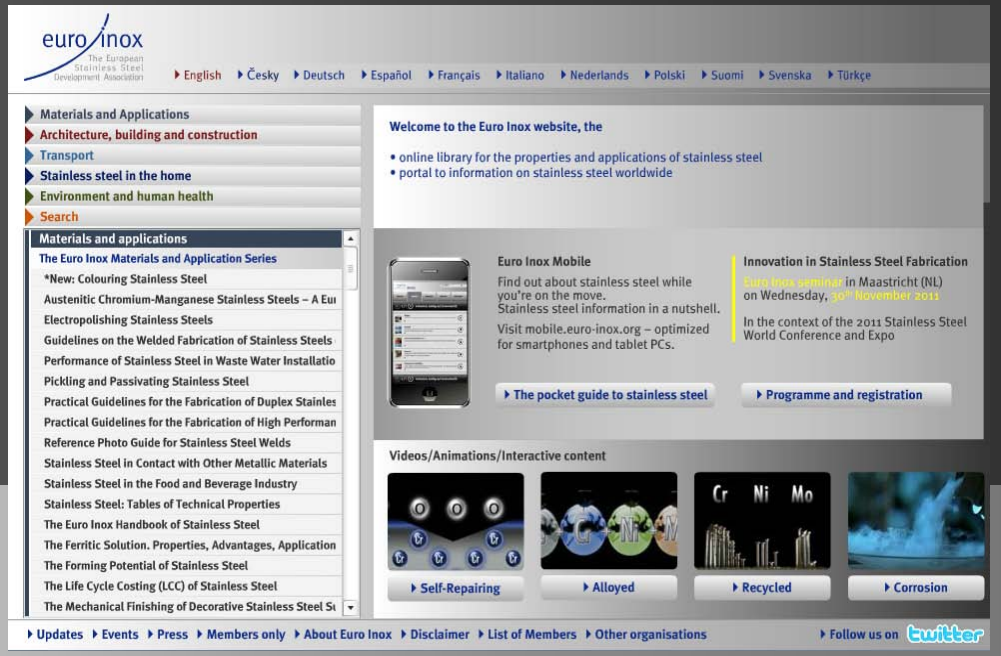
Focus on online communication:

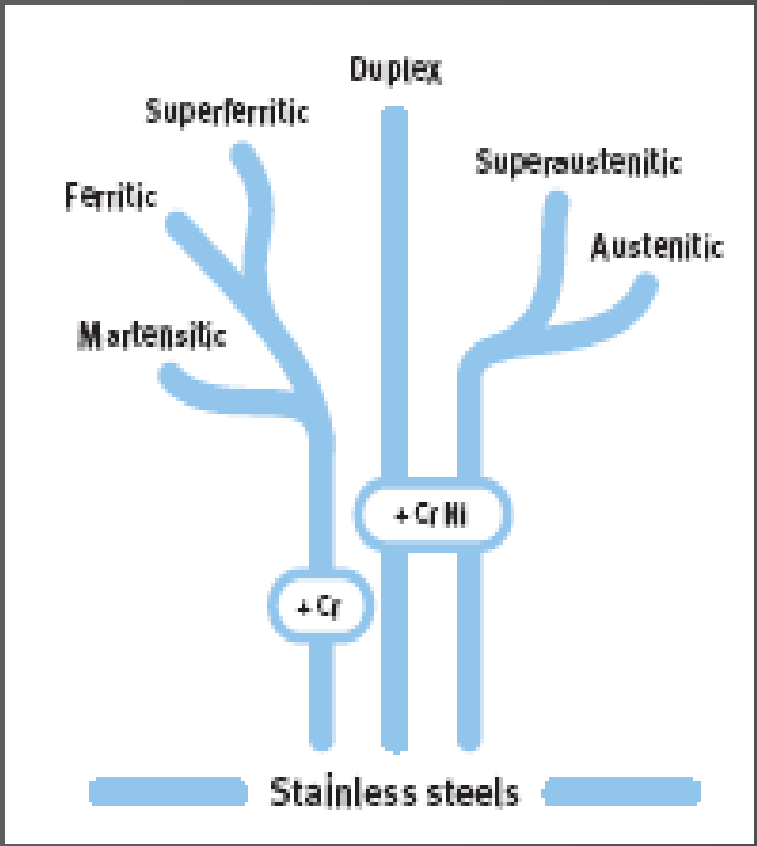
- about 140 documents available on the websites www.euro-inox.org and http://mobile.euro-inox.org

Other lines of activity:

- events
- helpdesk
- support of research
- image-building activities

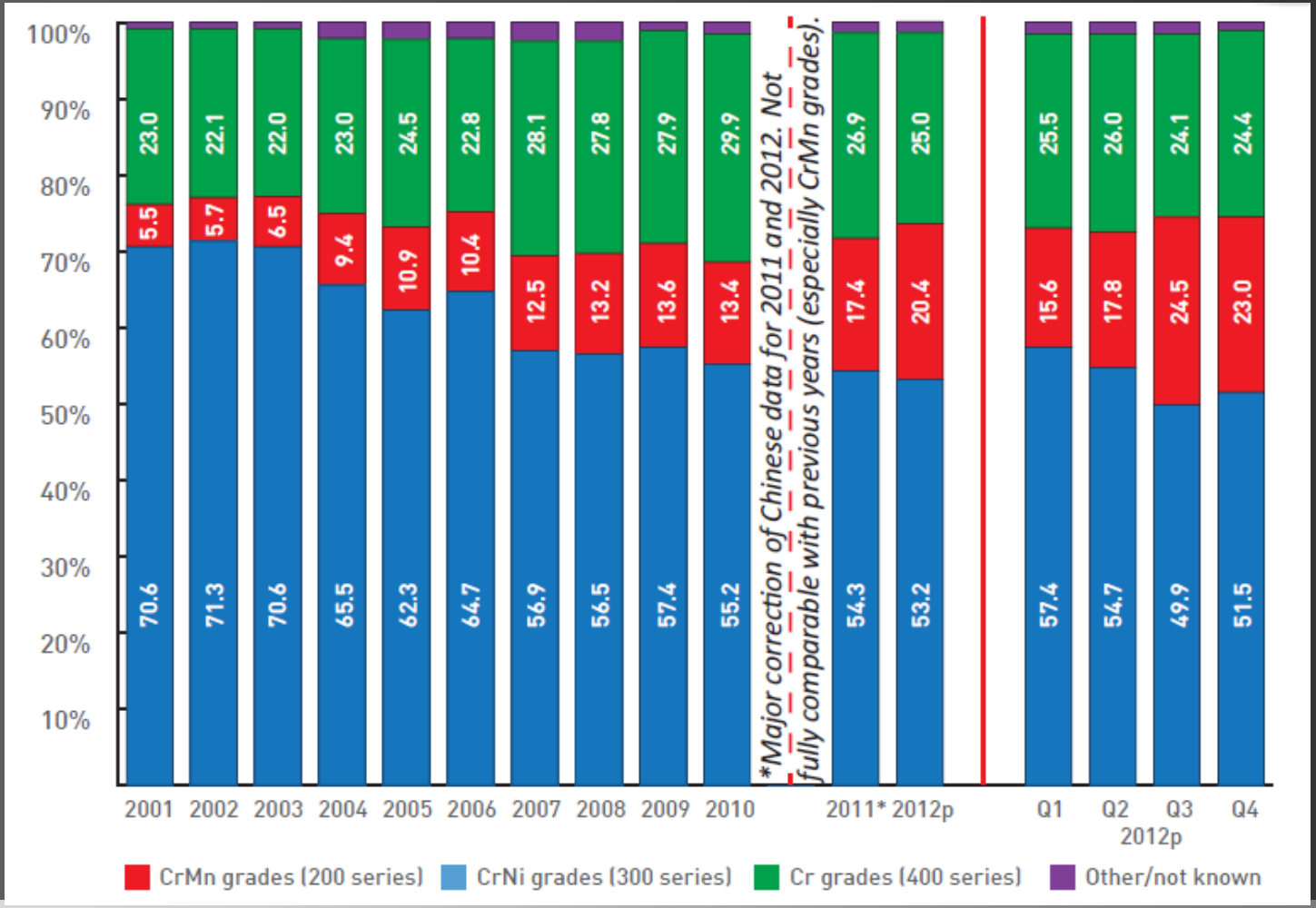


Grade selection process – when and why



- Austenitic
- Ferritic
- Martensitic and precipitation hardening
- Duplex

Grade selection process – when and why



Source: International Stainless Steel Forum (ISSF)

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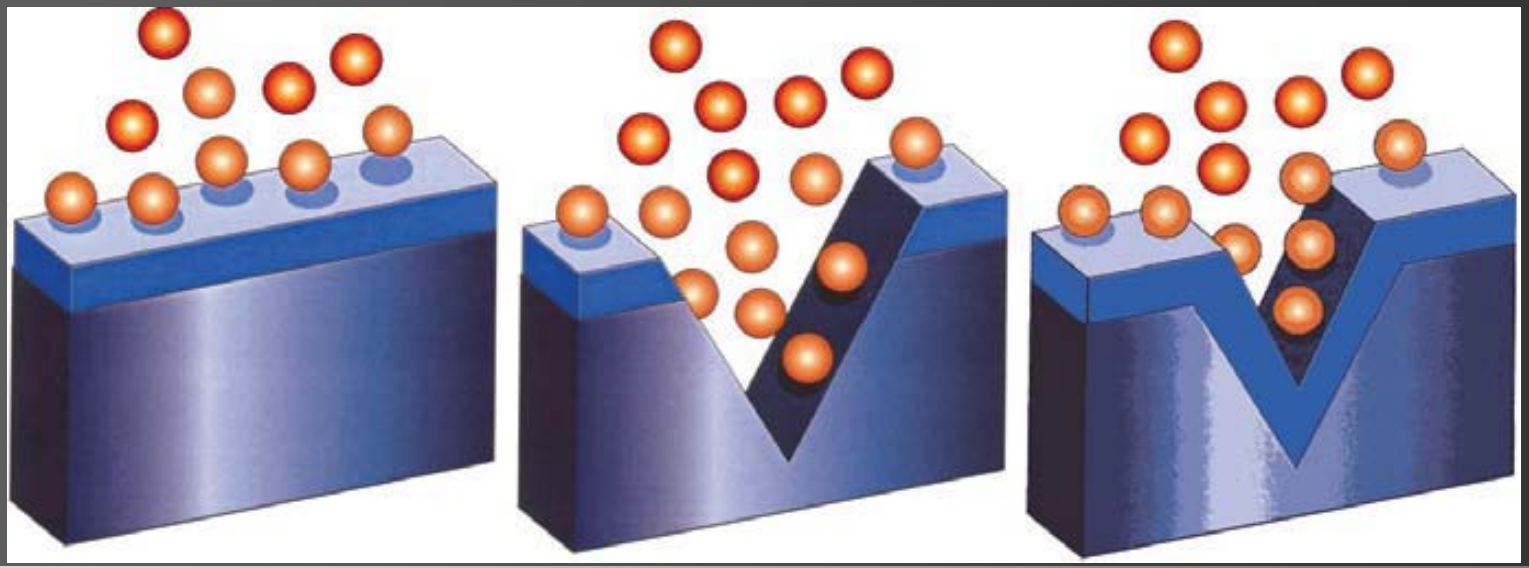
Grade selection process – when and why

- Stainless steels exhibit excellent resistance to corrosion due to a passive film or passive layer
- Passive film is affected by any heat treatment



Heat treatment in fabrication

In the delivery condition mostly no need for heat treatment:

- Austenitic : in solution annealed condition for highest corrosion resistance and ductility
- Duplex: in solution annealed condition for highest corrosion resistance and mechanical properties
- Ferritic: in annealed condition
- Martensitic: in annealed codition; hardening to follow

When and why to heat treat?

Photo: www.beststainless.com

Solution annealing
Austenitic stainless steels

- Heat treatment often required in fabrication after welding or thermal processing for optimum corrosion resistance, softness and ductility
- Cannot be hardened by heat treatment (but only as a result of cold working)

Solution annealing
Austenitic stainless steels

- Solution annealing in the range of 1040–1150 °C
- Cooling must be rapid (but it must be consistent with distortion limits)
- Avoid 500–900 °C temperature range

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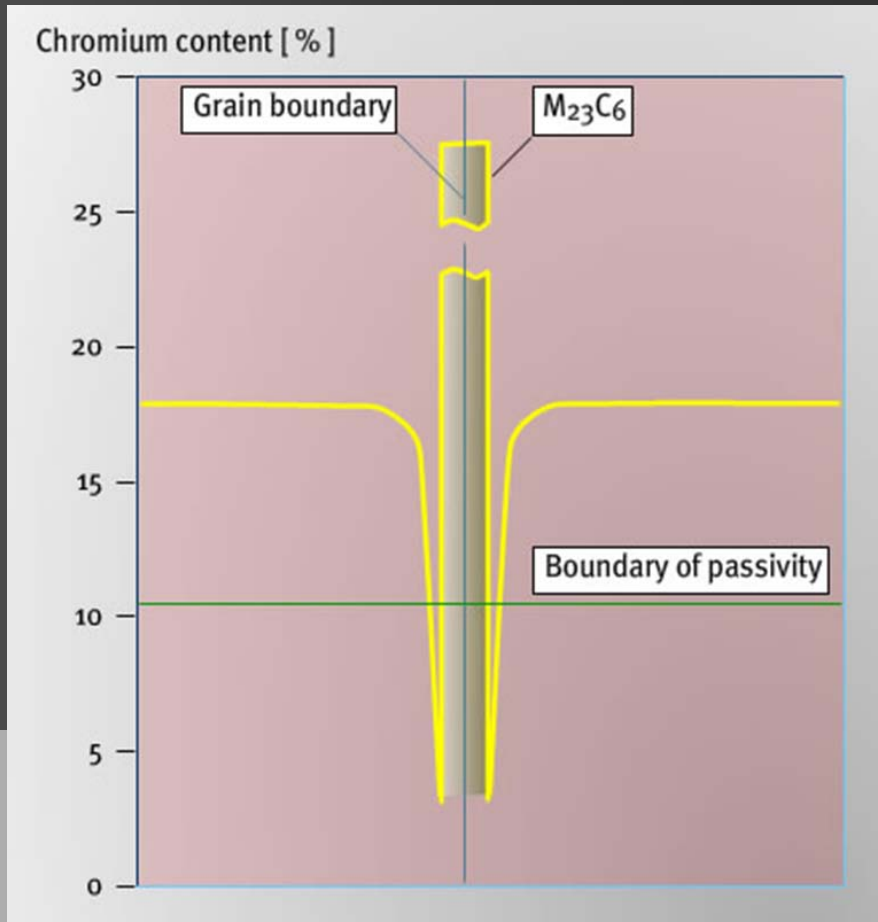
Solution annealing
Austenitic stainless steels

Sensitisation

- Risk of chromium carbide precipitation at grain boundaries and reduced corrosion reistance
- Forming of chromium carbide ($Cr_{23}C_6$)
- High carbon steels



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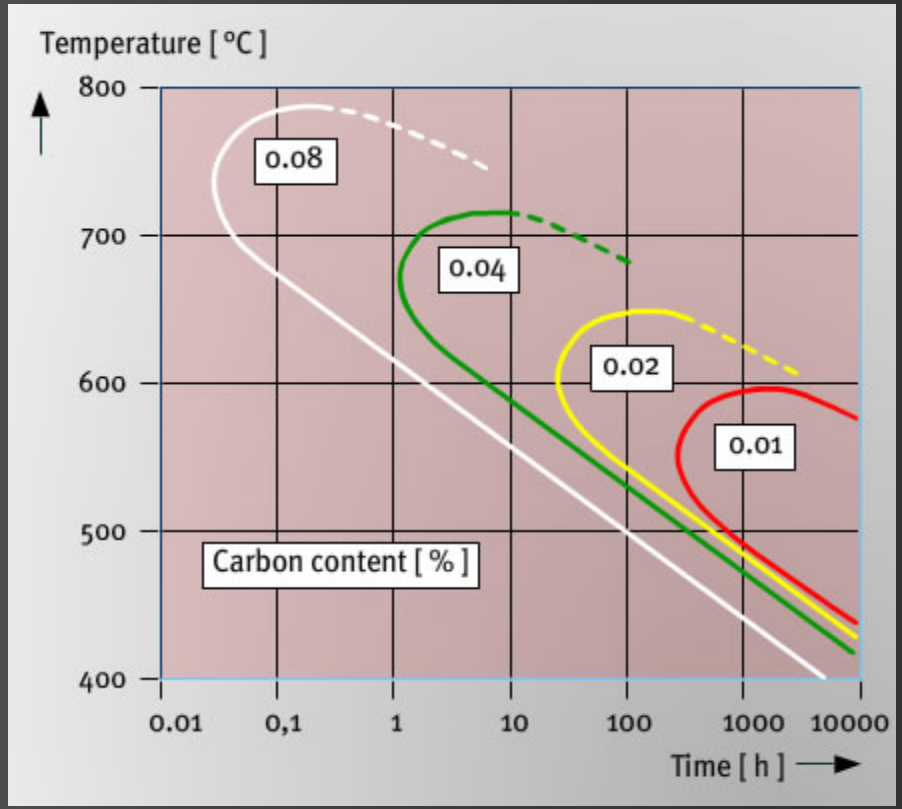
Solution annealing
Austenitic stainless steels

Chromium carbide formation is delayed with lower carbon content

Avoiding sensitisation:

- Solution annealing
- Stabilisation with Ti or Nb
- Reducing the carbon content



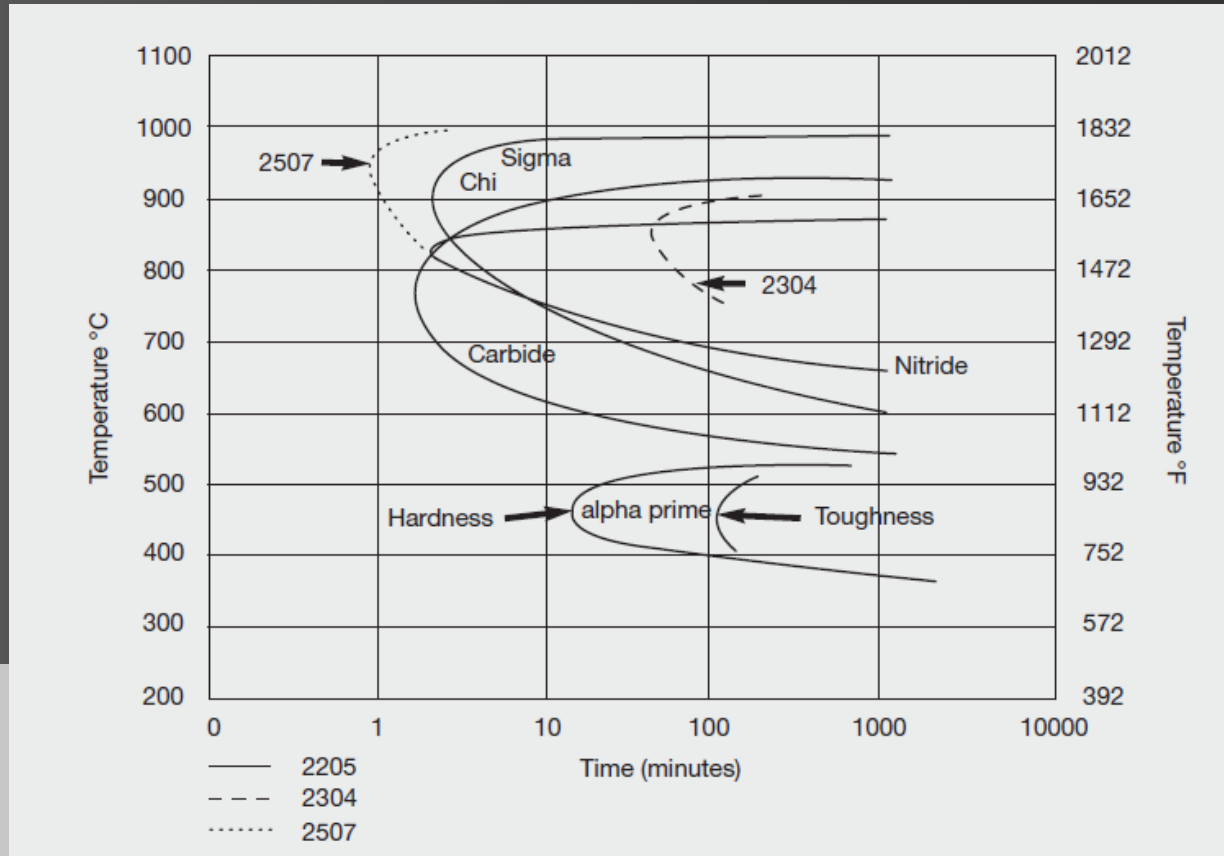
Solution annealing
Duplex stainless steels

- Full solution annealing followed by rapid cooling for restoring mechanical properties and corrosion resistance

Grade	EN Number	UNS Number	Minimum annealing T (°C)
2101	1.4162	S32101	950
2202	1.4062	S32202	980
2304	1.4362	S32304	950
2205	1.4462	S32205	1020
2507	1.4410	S32750	1040

Solution annealing
Duplex stainless steels

- With the welding the time at temperatue before precipitation of intermetallic phases is being used



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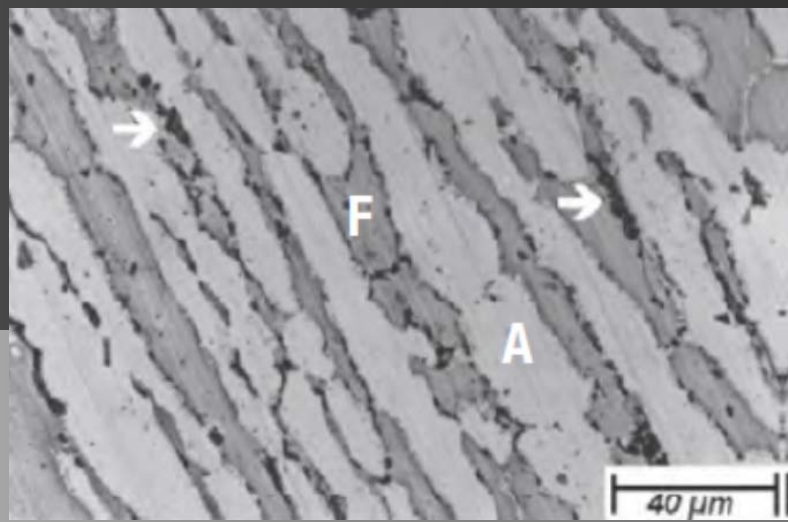
Solution annealing
Duplex stainless steels

Intemetallic phases

- Sigma, chi phase, alpha prime, carbides, nitrides, Laves

Approximate temperature ranges to avoid

- Sigma phase formation 700–950 °C
- Carbide precipitation 450–800 °C
- 475 °C embrittlement 300–525 °C



Solution annealing
Duplex stainless steels

Time

- Conservative: comparable to the the total time in 650–980 °C range subsequent to the previous full annealing

Additional measures

- Warping and distortions are likely, because soft at annealing temperatures (support!)

Cooling

- Water

Photo: Acroni (SI)

Solution annealing
Duplex stainless steels

Testing for absence of detrimental phases as to ASTM A 923

- Metallographic examination
- Charpy impact testing
- Corrosion testing
- Many fabricators have adopted this test as a part of their qualification for welding procedures

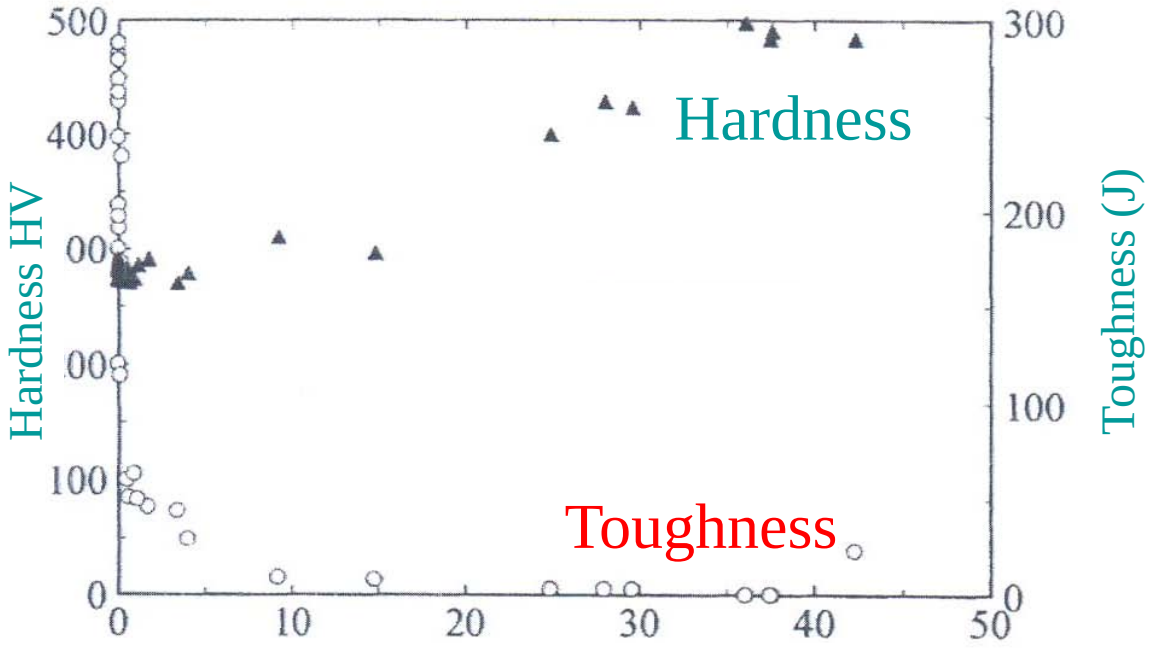
No similar EN standard!

Photo: Acroni (SI)

Solution annealing
Duplex stainless steels

ASTM A 923, Method B - Charpy impact testing

- For 2205
- min. 54 J for base metal, HAZ and weld metal



Annealing

Ferritic stainless steels

- Supply condition annealed
- Not hardeneded by quenching

- The only heat treatment is annealing
  - Relieved stresses developed during welding or cold working
  - Subcritical annealing (process)
  - Full annealing

Annealing

Ferritic stainless steels

The ferritic stainless can be divided into two groups:

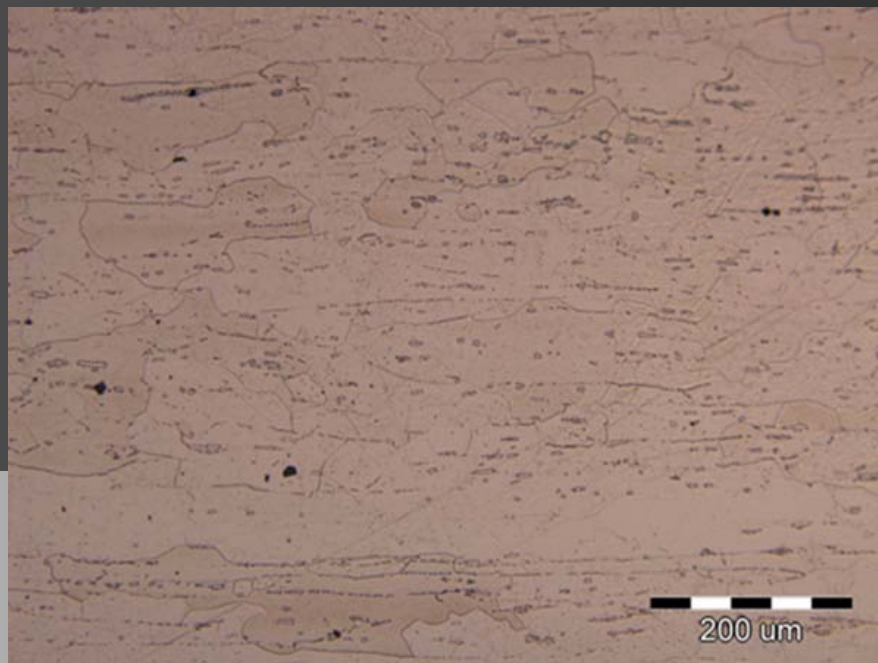
- Conventional ferritics, such as types 405, 409, 430 and 446
- Low-interstitial ferritics, such as types 444, superferritics

- Annealing – for more homogenous structure by dissolving transformation products formed during welding.
- Post heat treatment of the low-interstitial ferritics is generally unnecessary and is frequently undesired

Annealing

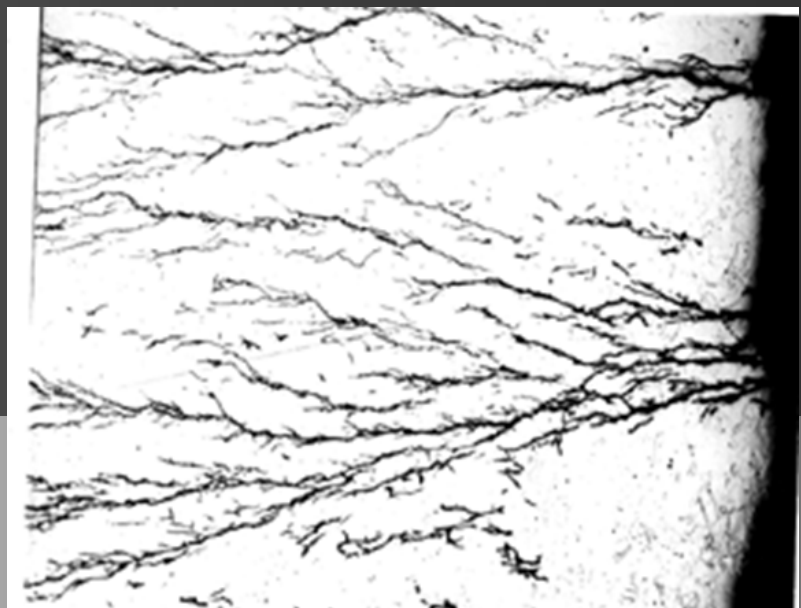
Ferritic stainless steels

- 475 °C embrittlement – common to the ferritic grades; can be developed from prolonged exposure to, or slow cooling within, the temperature range from about 370–525 °C
- The effects of embrittlement increase rapidly with chromium content



Stress relieving

- Cold worked austenitic stainless ⇒ strain induced martensite
- Stress corrosion cracking (SCC), which relies on tensile stresses as part of the failure mechanism
- Reduced risk of distortion during forming or machining



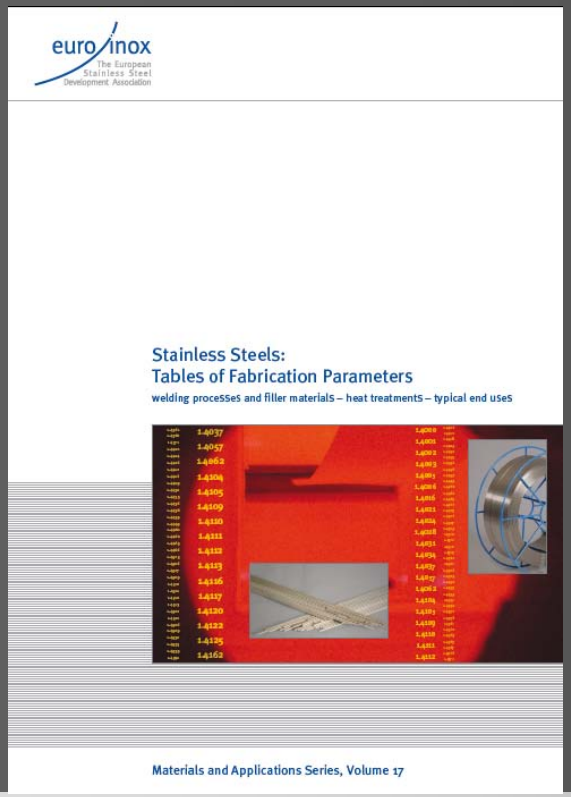
Stress relieving

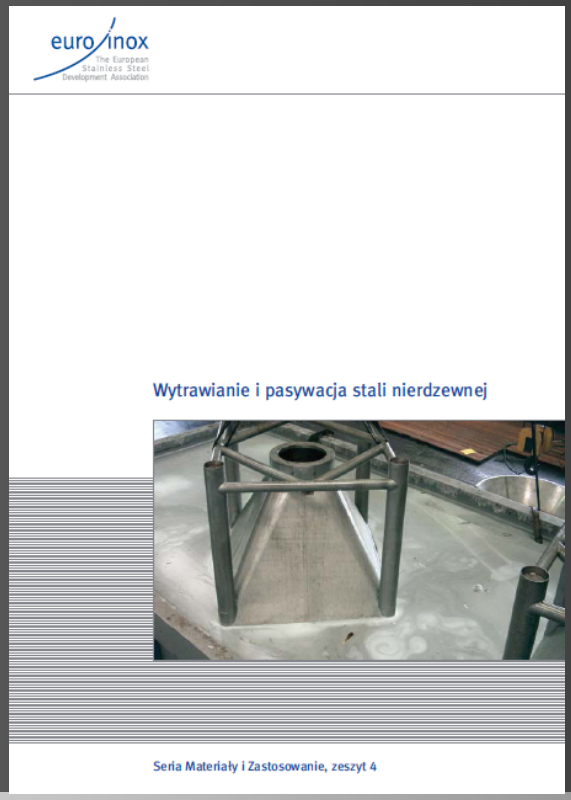
- Below 400 ^{o}C is acceptable practice, but results in only modest stress relief
- Full solution annealing removes all residual stresses in austenitics, but is not practical
- Stress relieving of duplex is not recommendable
- Stress relieving of martensitics and ferritics weldments will temper weld and HAZ
-

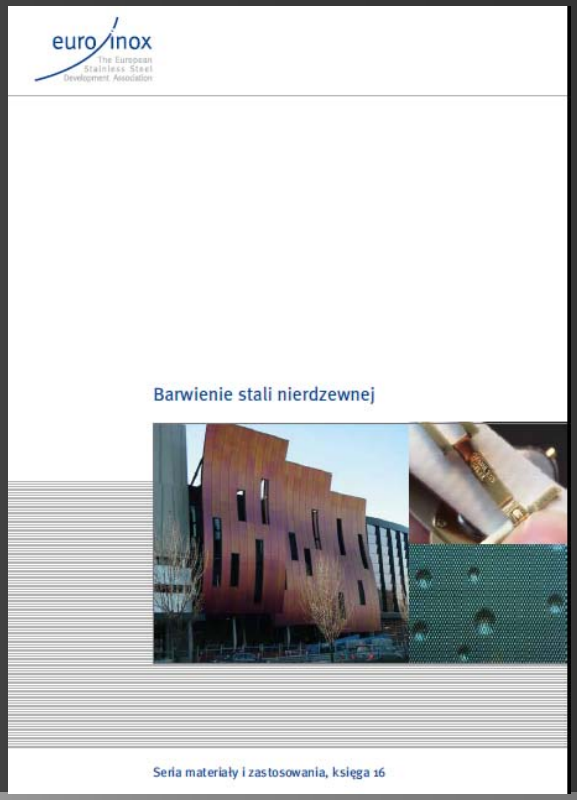
Pickling and passivation

- After heat treatment surfaces must be metallurgically clean no matter how
  - Mechanical (grinding, polishing, bead blasting)
  - Chemical (pickling, passivating)
  - Mechanical + chemical (electropolishing)

Support available from Euro Inox







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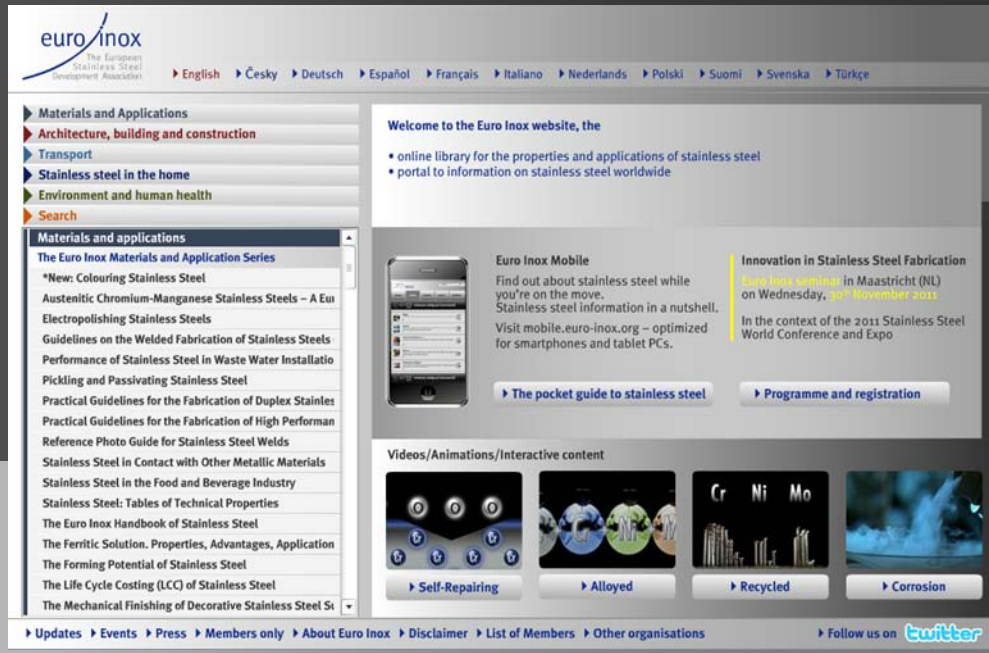
Support available from Euro Inox

Euro Inox provides a wide range of advisory publications in up to 14 languages

http://www.euro-inox.org
http://mobile.euro-inox.org



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