OUTOKUMPU

Nexus

Boilers & Opslagvaten

Duplex Stainless Steel

Stainless Steel – what's that?

- Austenitic 18Cr + 8Ni + (2Mo)

✓ Excellent formability and weldability
✓ Good resistance to local corrosion
✓ Sensitive to Stress Corrosion Cracking

- Duplex 22Cr + 1.5 - 5 Ni

✓ Combination of austenitic & ferritic structure
✓ Not sensitive to SCC
✓ Good weldability and machinability
✓ High mechanical properties
✓ Low alloy content – price stable

- Ferritic 20Cr + (2Mo)

✓ No Ni-content - price stable
✓ Not sensitive to SCC
✓ Limited welding and elongation properties

Less is more...

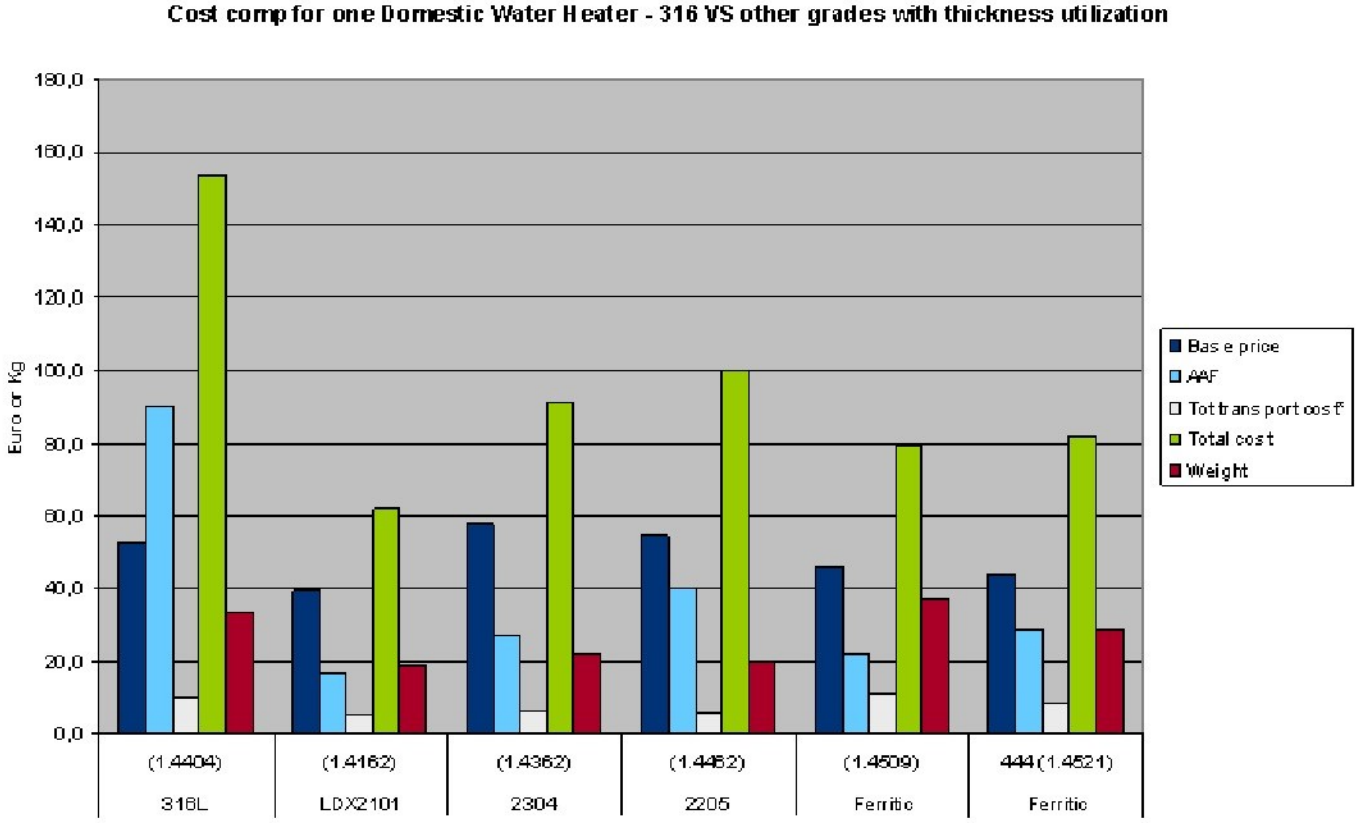
EN13445 at 10 bar Ø 500 mm and 100˚C can serve to illustrate thickness differences between austenitic, duplex and ferritic grades. If the strength of the material is used according to this norm the weight of one boiler (for example around 250 litres) will differ and have a direct impact on:

- Base price
- AAF
- Transport costs

Example info

316L	*1.8 mm*
LDX	*1.0 mm*
2304	*1.15 mm*
2205	*1.0 mm*
1.4509	*1.95 mm*
444	*1.52 mm*

Base price 1 - 2 mm, December 2010



Some References

Country	Company	Grade
Sweden	BORÖPANNAN	Duplex
Norway	OSO HOTWATER	LDX2101
UK	KINGSPAN RANGE CYLINDERS	LDX2101
	HEATRAE SADIA	2304 / LDX2101 / 2205
	TELLFORD COPPER	2304
	GLEDHILL BP	LDX2101
	FABDEC	LDX2101
	GRAHAM ENGINEERING	LDX2101
	RM SOLAR	2304 /LDX2101
France	TANK INOX	LDX2101
USA	HEAT TRANSFER PRODUCTS	LDX2101 / 316L
Germany	VIESSMANN	LDX2101
Schweiz	ECOTHERM	LDX2101
Spain	DEPOSITOS COBALLES	2205
Italy	RIELLO / OEMEPPI	LDX2101
Russia	FGUP PPO EVT	LDX2101
Greece	MALTEZOS	2304

Chemical composition %

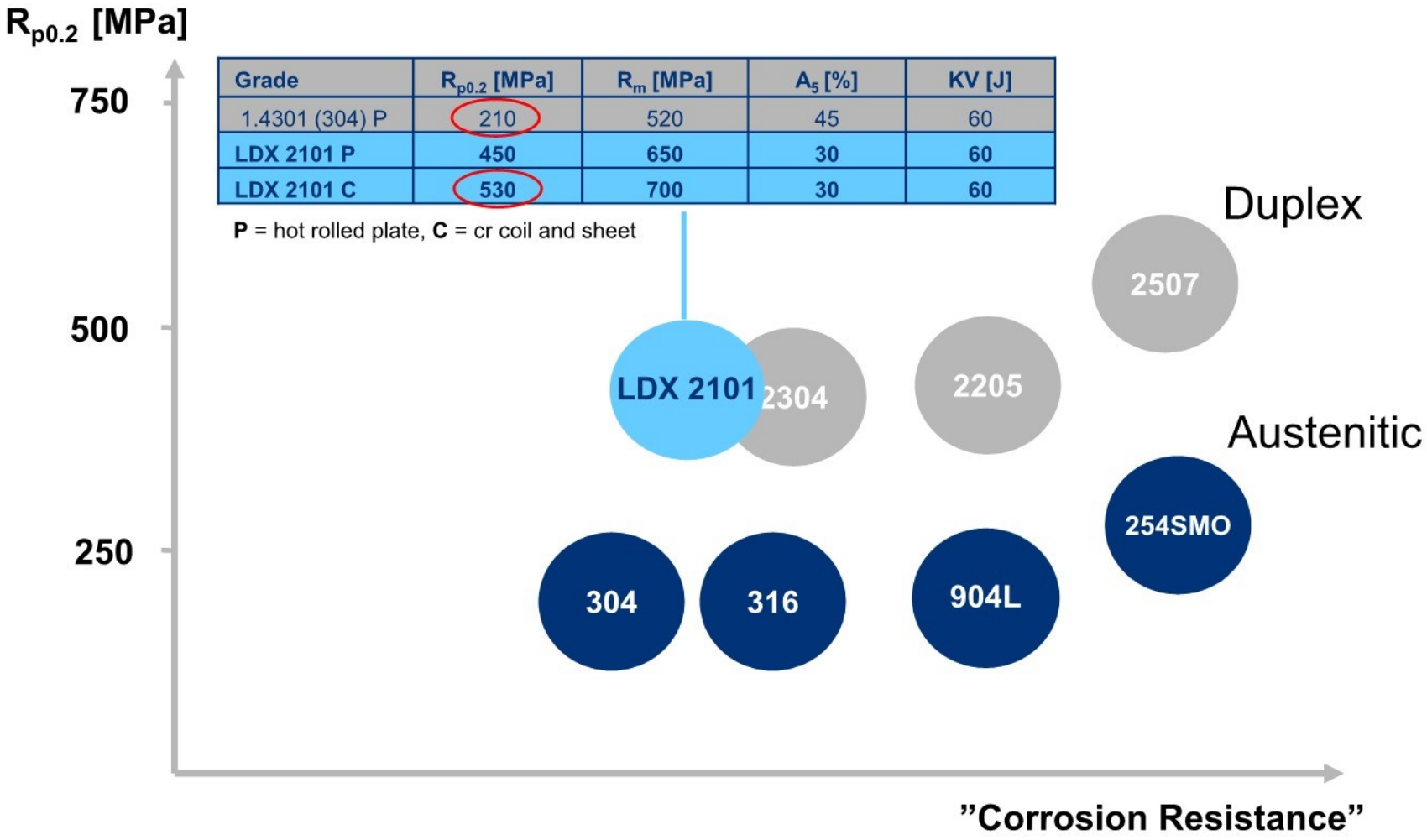
Typical chemical composition weight %									
Outokumpu	EN	ASTM	Cr	Ni	Mo	N	PRE*	$R_{p0.2}$**	
LDX 2101®	1.4162	S32101	21.5	1.5	0.3	0.22	26	450***	Lean Duplex
2304	1.4362	S32304	23	4.8	0.3	0.10	26	400	Duplex
2205	1.4462	S32205	22	5.7	3.1	0.17	35	460	Duplex
2507	1.4410	S32750	25	7	4	0.27	43	530	Super Duplex
4501	1.4501	S32760	25.4	6.9	3.8	0.27	42	530	Super Duplex
4307	1.4307	304L	18.1	8.1	-	-	18	200	Austenitic
4404	1.4404	316L	17.2	10.1	2.1	-	24	220	Austenitic
4432	1.4432	316L	16.9	10.7	2.6	-	25	220	Austenitic
904L	1.4539	N08904	20	25	4.3	-	34	220	Austenitic
254 SMO®	1.4547	S31254	20	18	6.1	0.20	43	300	Super Austenitic
4529	1.4529	N08926	20.5	24.8	6.5	0.20	45	300	Super Austenitic

* PRE = %Cr + 3.3x%Mo + 16x%N
** [MPa] Hot rolled plate, min values at 20°C according to EN 10088
***Not yet in EN 10088, Rp0.2 according to ASTM A240

Utilizing the strength of Duplex

Grade	$R_{p0.2}$ [MPa]	R_m [MPa]	A_5 [%]	KV [J]
1.4301 (304) P	210	520	45	60
LDX 2101 P	**450**	**650**	**30**	**60**
LDX 2101 C	**530**	**700**	**30**	**60**

P = hot rolled plate, **C** = cr coil and sheet



Pitting corrosion

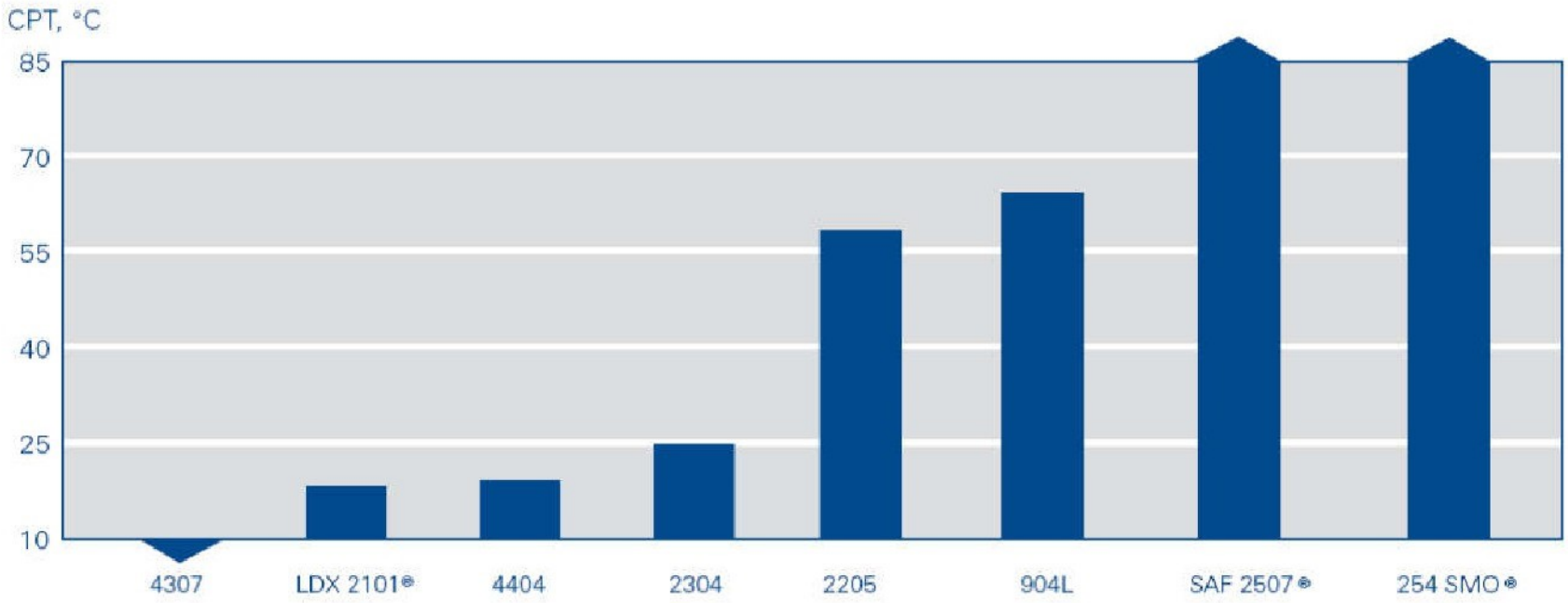
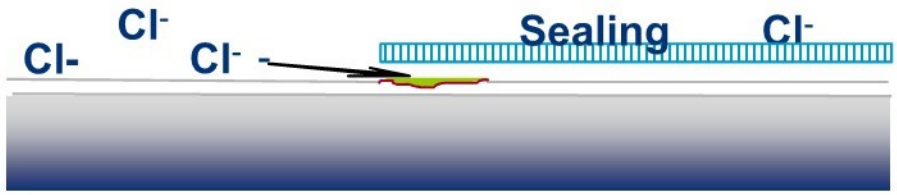
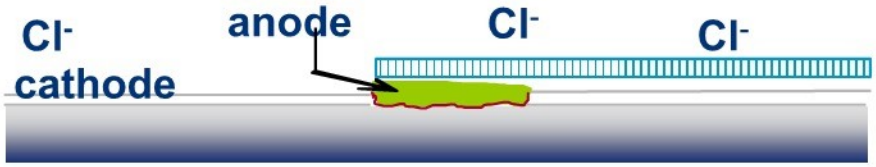


Fig. 5. Typical critical pitting corrosion temperatures (CPT) in 1M NaCl measured according to ASTM G150 using the Avesta Cell. Test surfaces wet ground to 320 mesh. CPT varies with product form and surface finish.

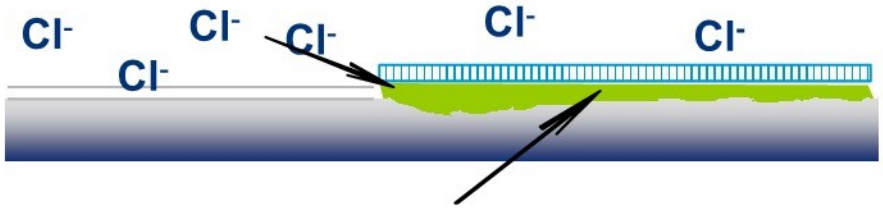
Corrosion – Crevice corrosion



The oxygen content in the narrow crevice decrease and the amount of acidic corrosion products increase
Chloride ions destroy the passive layer



A galvanic cell is formed between the bare metal inside the crevice and the passive layer outside



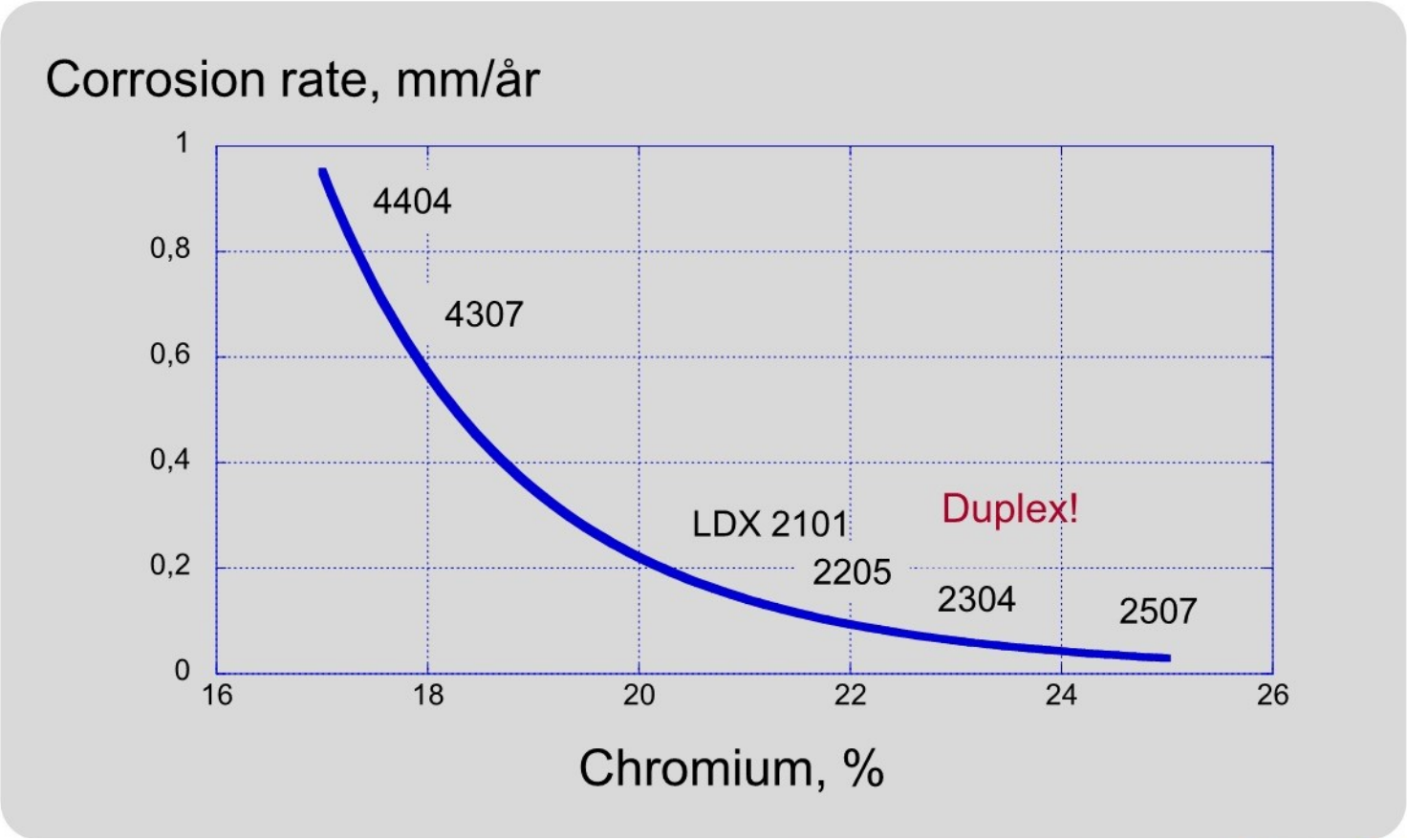
pH decreases and the chloride content increases inside the crevice
The attack grows!

$$Fe^{2+} + H_2O \rightarrow FeOH^{+} + H^{+}$$
$$Cr^{3+} + H_2O \rightarrow CrOH^{2+} + H^{+}$$

High propagation rate!

Uniform corrosion

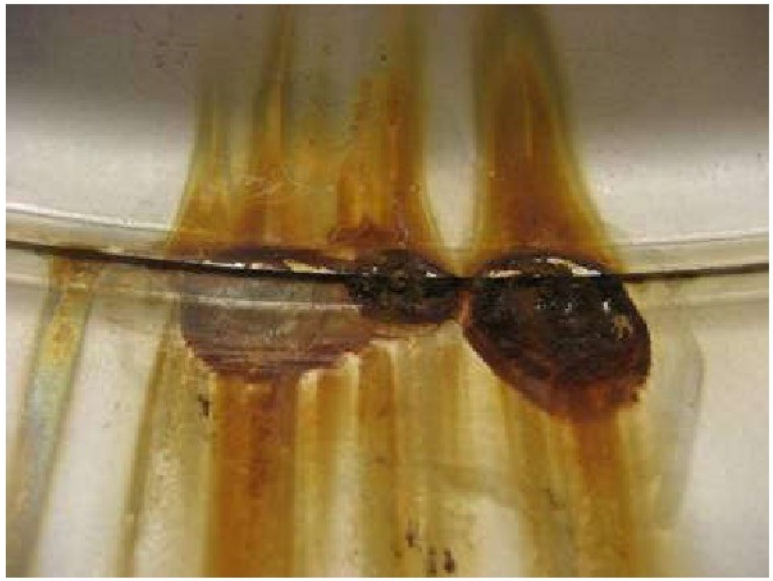
Effect of Cr on the corrosion rate of SS in batch digesters (Pulp & Paper)



Material welding of Duplex

- Good weldability
- TIG-GTAW, Laser and PAW most common
- Use filler metal: Avesta LDX 2101® / 22 9 3 NL
- Nitrogen additions to shielding / backing gas gives positive effect on strength and corrosion resistance
- Shielding gas (TIG): Ar + 1-3% N_2, Ar + 10-30% He + 2% N_2, Ar
- Backing gas (TIG): 90% N_2 + 10% H_2, 95% N_2 + 5% H_2, N_2
- Use back gas also when repair and tack welding
- Post weld heat treatment not necessary
- LDX2101 is suitable for autogenously welding and welding without filler
- Welding decreases corrosion resistance! Effect less with good backing gas shielding. Post weld cleaning is recommended!

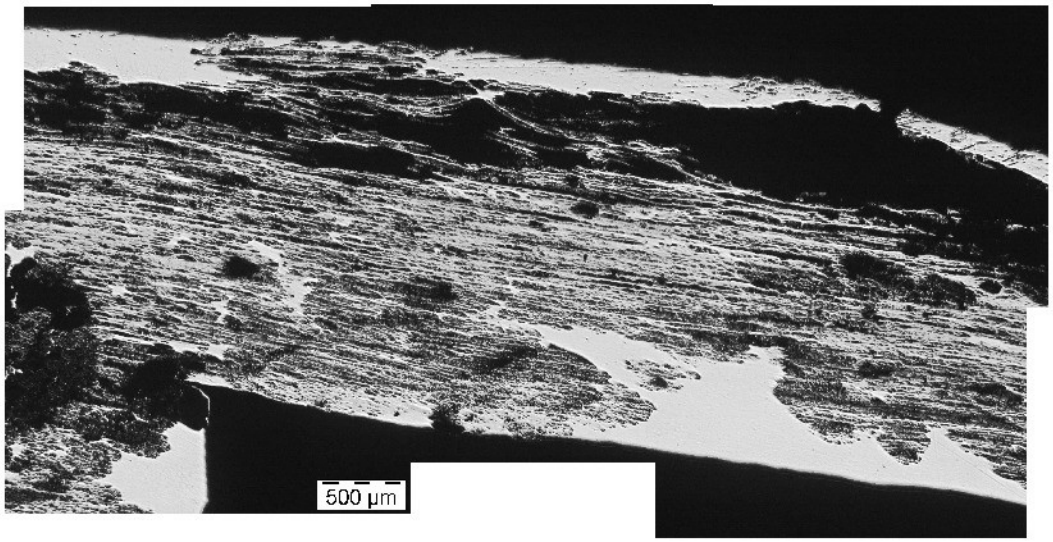
Crevices and weld oxide reduce corrosion resistance!



Severe crevice corrosion of LDX 2101®

Worst case example

Crevice design in combination with no post weld cleaning
(remaining weld oxides inside crevice)



Common Standards & Approvals

- **Material standards and approvals:**
  - EN 10088-2 — Stainless Steels – Sheet/plate and strip for general purposes
  - ASTM A480 — General requirements for flat-rolled stainless…
  - EN 10028-7 — Flat products for pressure purposes – Stainless Steels
  - ASTM A240 — …stainless steel plate, sheet and strip for pressure vessels
  - PMA EN 1.4162 –TÜV (LDX 2101 only)
  - ASME Code Case 2418 - Plate, sheet and strip (LDX 2101 only)

- **Application standards and design codes:**
  - EN 13445 — Unfired pressure vessel
  - ASME VIII-1 — ASME (American Society of Mechanical Engineers), Boiler and Pressure Vessel Code
  - API 650 — American Petroleum Industry, “Welded Steel Tanks for Oil Storage”
  - ADR — International carriage of dangerous goods by road
  - RID — International carriage of of dangerous goods by rail
  - ENV 1993-1.4 — Eurocode 3: Design of Steel Structures
  - Werkstoffblatt LDX2101 — TÜF approval Germany

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