Roll-bonded clad plates

Our cost-efficient answer to corrosion

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www.voestalpine.com/grobblech

voestalpine
ONE STEP AHEAD.

Ready for the future

voestalpine Grobblech is the world's leading manufacturer of roll-bonded clad plates. We offer clad plates, clad heads and clad cones from a single source. As a manufacturer with several decades of experience in roll bonding, we are your reliable partner in the linepipe, pressure vessel and apparatus industry. We understand our customers, provide the quality they need and have a large capacity to clad roll-bonded clad plates. These plates bring manufacturing and cost benefits during further processing.

Convincing advantages

- We have a large cladding capacity
- We run the world‘s most modern production line
- We offer a cost-efficient answer to corrosion
- We provide outstanding quality

Convincing advantages

We have a large cladding capacity

voestalpine Grobblech is the world´s leading producer of roll-bonded clad plates with 40 years of expertise. Our production capacity of 40,000 tons/year represents about one third of the entire worldwide capacity. This reduces our delivery times and consolidates our leading position in the market. We are able to supply huge single projects up to 10,000 tons within a reasonable period of time according to market requirements.

We run the world‘s most modern production line

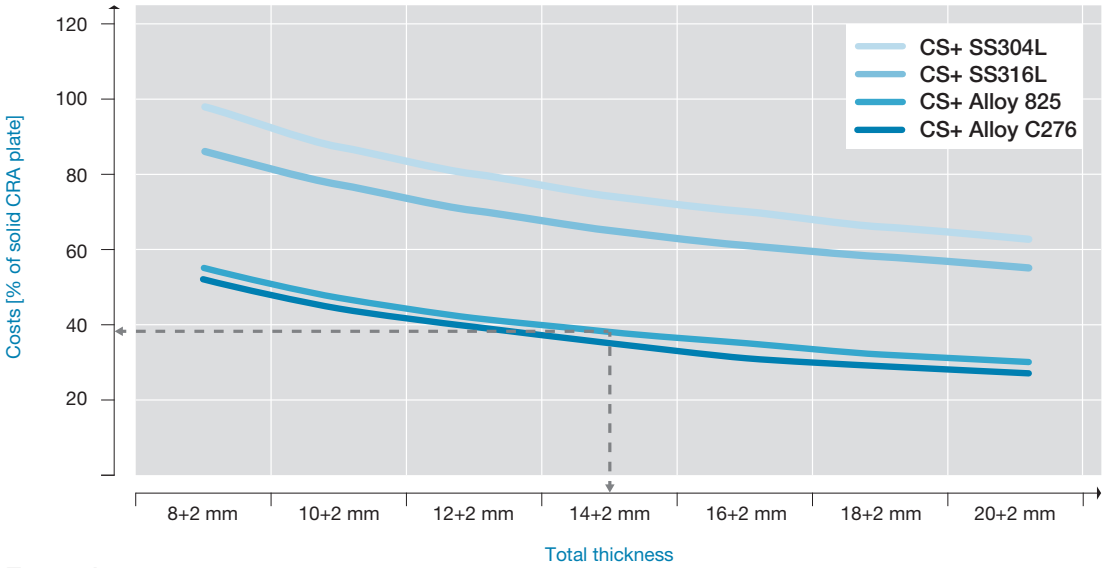
Our production equipment is highly automated and provides narrow tolerances concerning dimensions, flatness and surface.

We offer a cost-efficient answer to corrosion

Compared with solid corrosion-resistant alloy (CRA) plates, cost advantages can be achieved by using roll-bonded clad plates. Not only material costs, but also the costs of filler metals can be reduced. The thicker the base material, the lower the overall costs while maintaining consistent corrosion resistance.

Cost advantages

Roll-bonded clad plates compared with solid CRA plates



Example

The costs of a solid CRA plate of alloy 825 in thickness of 16 mm represent 100%. The costs of a roll-bonded clad plate of 14 mm carbon steel (CS) and 2 mm of alloy 825 (total thickness of 16 mm) count for only 38 %.

We provide outstanding quality

Our clad plates are made with ultra-clean base materials produced exclusively in our own steel plant in Linz. To achieve outstanding quality we exclusively use clad materials in best condition without any precipitations. Furthermore, we achieve an ultra-clean bonding area by using vacuum technology.

Typical fields of application

As reliable partner for roll-bonded clad plates, our typical fields of application are the refinery, petrochemical and chemical industry, oil and gas production as well as power plants and flue gas desulphurisation plants.

Refineries, petrochemical and chemical industry

- Fractionators
- Vacuum towers
- Coke drums
- Process pipes
- Columns
- Pressure vessels
- Reactors
- Washers
- Heat exchangers

Oil and gas production

- Clad flowlines
- Satenary riser pipes
- Slug catchers

Flue gas desulphurisation plants

- Flue gas channels
- Chimneys
- Flue gas scrubbers

Power plants

- Accumulator tanks
- Other applications

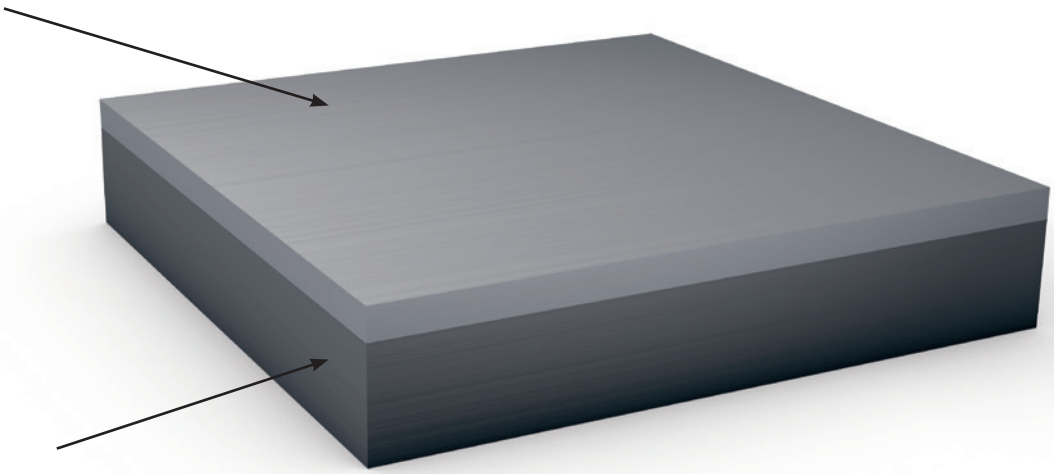
Roll-bonded clad plates

A thin layer of expensive corrosion-resistant alloy provides excellent corrosion protection while the thicker but less expensive base-material of high-strength carbon steel ensures adequate structural strength. A metallurgical bond between the two materials is achieved in a computer-controlled hot-rolling process. Roll-bonded clad plates are the economic solution for corrosion-resistant applications in refineries, oil and gas production, the chemical industry as well as in power plants and flue gas desulphurisation plants.

Definition

- Metallurgically bonded composite of two or more layers
- The bond is created by high temperature and high pressure
- A thin corrosion-resistant alloy (CRA) as clad material and thick carbon steel as base material is a typical combination.

Clad material
for corrosion protection



Base material
for static demands

Advantages of roll-bonded clad plates

- Advantages in comparison to **solid corrosion-resistant alloy (CRA) plates**:
  - Reduced material costs
  - Less weight due to reduction of wall thicknesses
  - Reduction of weld length due to larger dimensions
  - Lower cost of filler metal
  - Superior heat conductivity

- Advantages in comparison to **overlay welding:**
  - Improved surface conditions
  - No dilution from the base material
  - Homogenous chemical composition

- Advantages in comparison to **explosive cladding:**
  - Higher bonding quality
  - Reduction of weld length due to larger dimensions
  - Use of thinner clad material is possible
  - No welds in the claddings for wide plates

- Advantages in comparison to **rubber coatings and linings:**
  - Metallurgical bonding
  - Lower maintenance costs

Clad linepipe plates

We are the world's second-largest producer of roll-bonded clad linepipe plates. Roll-bonded clad plates are used for the manufacture of clad linepipes.

Highest resistance to sour gas

Roll-bonded clad plates are used for the manufacturing of clad linepipes. The sour gases occurring in linepipes used for the transport of oil and gas are highly corrosive. Only the highest-quality materials are capable of withstanding this aggressive medium. Our roll-bonded clad linepipe plates with corrosion-resistant claddings meet these extreme requirements. We are the world's second-largest producer of roll-bonded clad linepipe plates.

TMCP and protective cladding

We provide thermomechanically rolled and accelerated cooled (TMCP) clad plates. This in-line process leads to high strength and excellent toughness combined with best weldability of the base material and maintains the extreme corrosion resistance of the protective cladding. A typical material combination is X65 with stainless steel 316L. We also offer nickel-based alloy 625 and 825 as cladding.

Metallurgical bond

Our pipe partners process these clad plates into metallurgically bonded clad linepipes. The metallurgical bonding of the clad linepipes withstands the highest mechanical stress and dynamic loads, making the pipes especially suited to deep-sea applications under highly corrosive conditions.

Reeling and riser pipes

- More cost-efficient reeling of pipelines in comparison to on-board welding
- Roll-bonded clad plates for risers, bends and fittings
- Excellent properties of metallurgically bonded clad plates for the highest degree of compression strength

Delivery condition

The conventional delivery condition of clad plates used in clad pipes is quenched and tempered. We also can provide thermomechanically rolled and accelerated cooled (TMCP) clad plates. This online processing leads to high strength and excellent toughness combined with best weldability of the base material and properly maintains corrosion properties of the clad material.

Clad heads and cones

We produce clad heads and clad cones from roll-bonded clad plates in-house. In one package we supply shell plates, heads and cones for pressure vessel manufacture from a single source, available with carbon steel, low-alloyed steel as well as cladded.

Plates, heads and cones from one source

Benefits for our customers:

- Advantages in processing, especially regarding welding when using the same steel for shell plates and heads
- Technical support and coordination from one research and quality department
- Coordinated production and delivery of shell plates and heads from a single source
- Reduced costs for our customers

Claddings

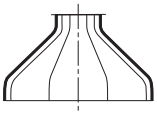
We offer ferritic and austenitic stainless steels (Cr, CrNi, CrNiMo), nickel and nickel-based alloys, copper and copper-nickel-alloys as cladding materials for clad heads and cones.

Products and dimensions

single-piece heads (pressed):
diameter: max. 3,700 mm*
thickness: max. 160 mm

multi-piece heads (pressed):
diameter: max. 10,000 mm
thickness: max. 120 mm

single-piece heads (flanged):
diameter: max. 6,500 mm*
thickness: max. 65 mm

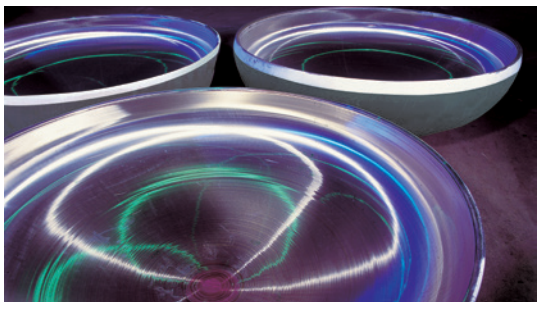


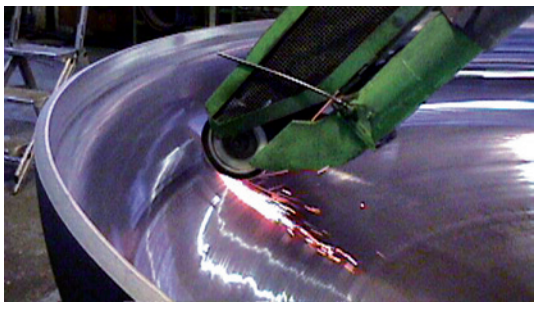
multi-piece cones (pressed):
diameter: max. 10,000 mm
thickness: max. 120 mm

*from 3,400 – 6,500 mm with one weld seam

- Belt grinding or glass-bead blasting of clad surface
- Egde preparation for welding
- Heat treatment corresponding to material requirements; water quenching up to a diameter of 6,500 mm

For more information about heads, please also refer to our special brochure "Heads and Cones".



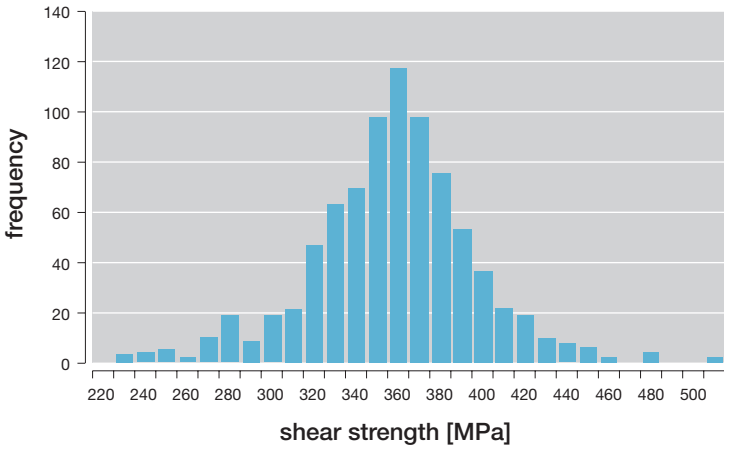


Quality

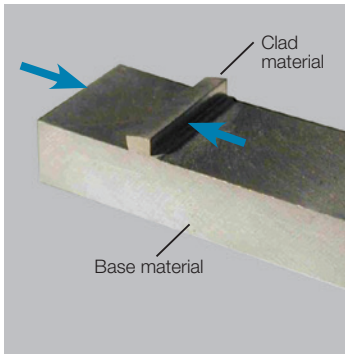
The high quality of roll-bonded clad plates is based on the mechanical properties of the base material, optimally combined with the corrosion resistance of the cladding material. The bond is inseparable. A perfect surface finish completes this high-end product.

Bond quality

The metallurgical bond between base and clad material is created by high pressure at high temperature. The bond is inseparable and far exceeds the minimum shear strength of 140 MPa required by ASTM.

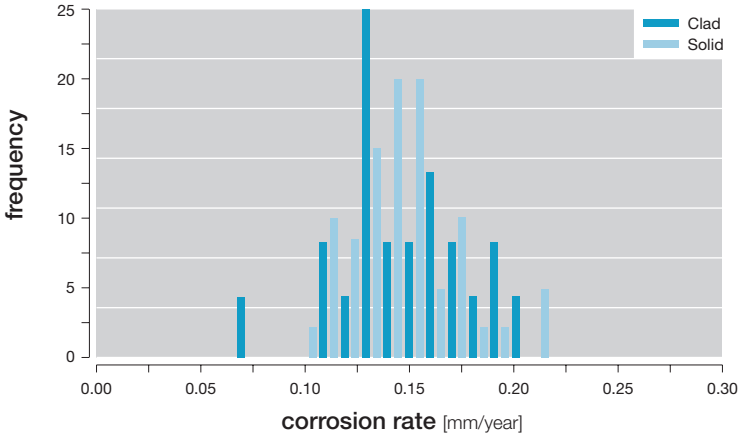


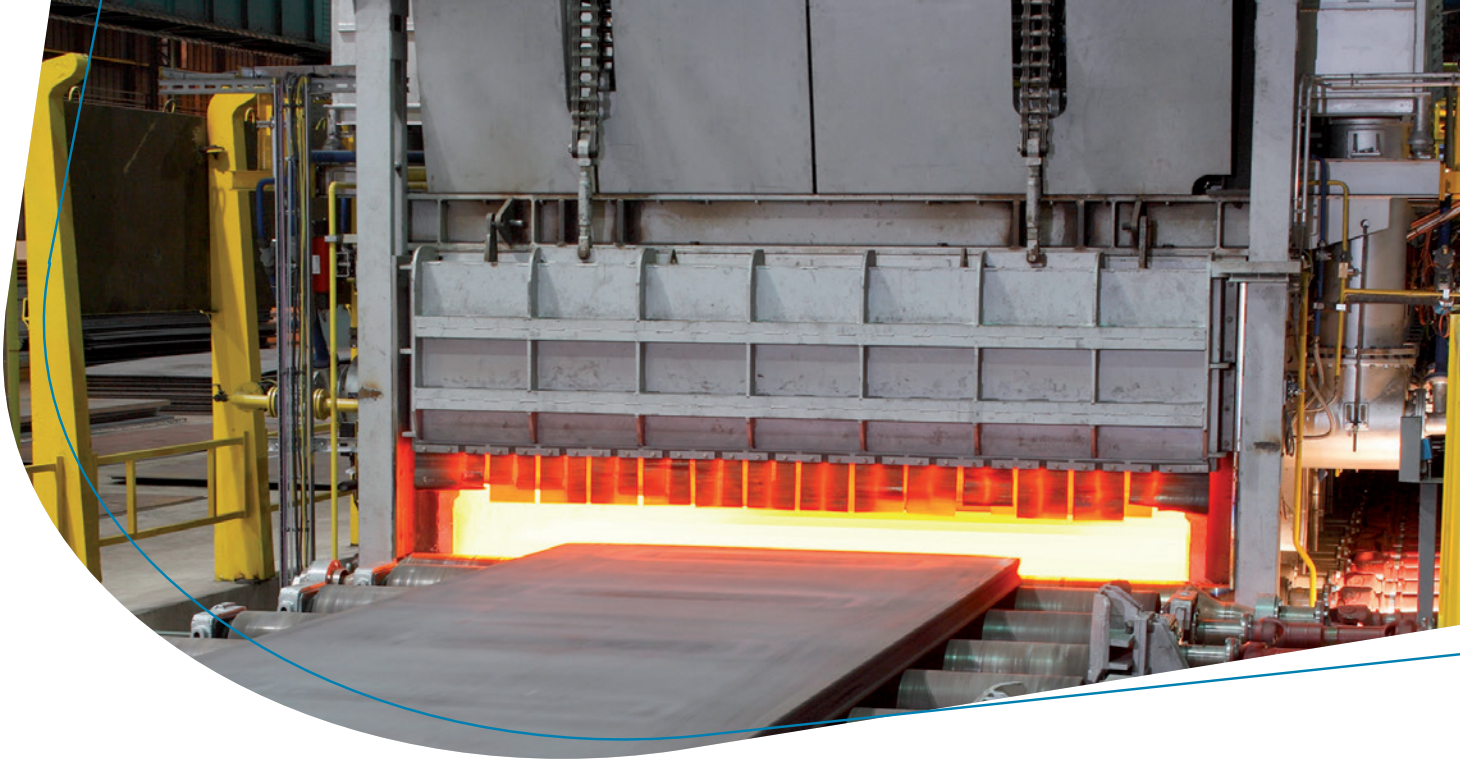
min. 140 MPa acc. to standard (ASTM A264)



Corrosion resistance

The corrosion resistance of clad material is equivalent to that of solid material.





Heat treatment

Based on the chemical composition, the mechanical-technological properties of the base material as well as the corrosion properties of the clad material are adjusted by choosing the appropriate production route and heat treatment.

- As rolled with simulated testing
- Normalizing rolled
- Normalized (furnace)
- Normalized and tempered
- Quenched and tempered
- Thermomechanically rolled and accelerated cooled (TMCP)

Surface finish

The surface of the base material is usually „as rolled“ or shot blasted. The surface of the clad material is usually ground with a grain size of 80. Other grain sizes are available on request. Any additional future surface treatment (e.g. fine grinding) of the clad surface by the customer must be indicated at when ordering.

Reference values for roughness

- Clad material: ferritic and austenitic stainless steel, nickel-based alloys

Grain size	80
Depth of roughness Rt in µm	< 40
Mean roughness Ra in µm	< 4.5

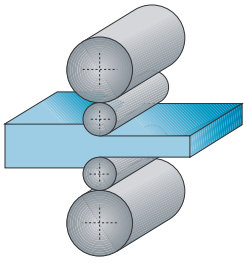
- Clad material: copper and copper alloys, nickel

Copper and copper alloys as well as nickel clad plates are ground with a grain size of 120.

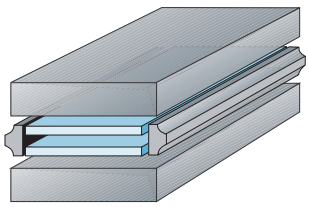
Cladding process

Our production equipment is highly automated and provides narrow tolerances concerning dimensions, flatness and surface.

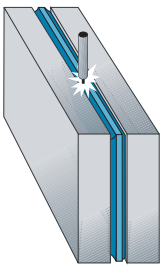
1. Rolling of base and clad material →



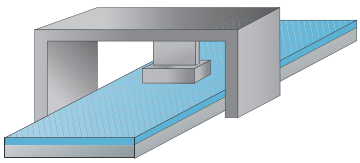
2. Package assembly →



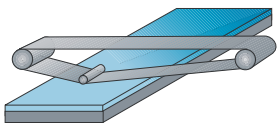
3. Package welding →



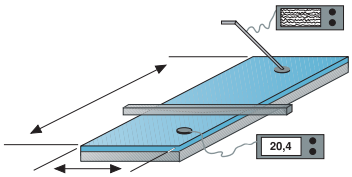
10. Ultrasonic testing ←



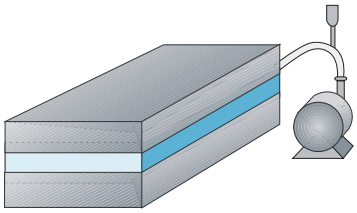
11. Grinding ←



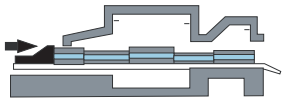
12. Final check ←



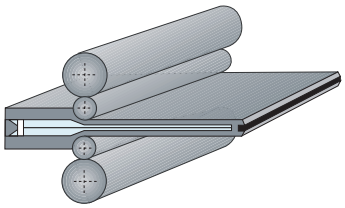
4. Evacuation



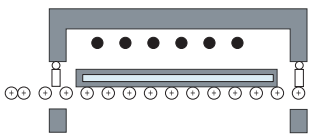
5. Reheating



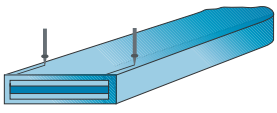
6. Rolling



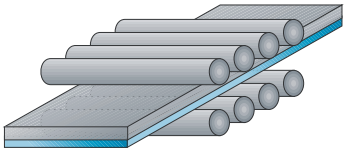
7. Heat treatment



8. Plasma torch cut



9. Levelling



We lead the way, so our partners will be one step ahead. Many years of partnerships with renowned companies impressively prove our point.

We talk solutions

That is why we will never be satisfied with excellent product quality alone. Comprehensive services and unlimited dedication to the challenges of our customers are at the core of our philosophy.

Highly specialized and closely linked, the companies of the voestalpine Steel Division have one common goal, which is providing our customers with optimized and individualized packages of benefits.

Progress through R&D

- Continual product and process development
- Innovative solutions for products and processes
- Independent and fully accredited testing facility on-site
- Simulations of material performance of weldability, deformation and edging behavior, fatigue tests and fracture mechanics
- Consultation in the fields of welding and processing

Product integrity by quality assurance

- Certified by Lloyds Register by ISO 9001
- Certified by the "Verband der Technischen Überwachungsvereine"
  - AD-Merkblatt W0/TRD 100
  - Pressure Equipment Directive PED 97/23/EC

A unique logistics package

- Partnerships with our clients and customers
- Reliable and flexible delivery performance
- Professional project management ensuring successful delivery of complex orders
- Dedicated mill-based project management team for order management from pre-production to post-production to support
- Complete project documentation package (inspection and testing plan, manufacturing specifications, ultrasonic testing procedures)
- Prompt reaction to inquiries
- Web-based customer service center with customer access to order confirmations, invoices, test certificates and order status

A strong partnership

- Close collaboration with our Group companies in order to obtain unique expertise and ensure the technological leadership of our products
- You can find more voestalpine product information at
  - voestalpine Böhler Welding (www.voestalpine.com/welding/group)

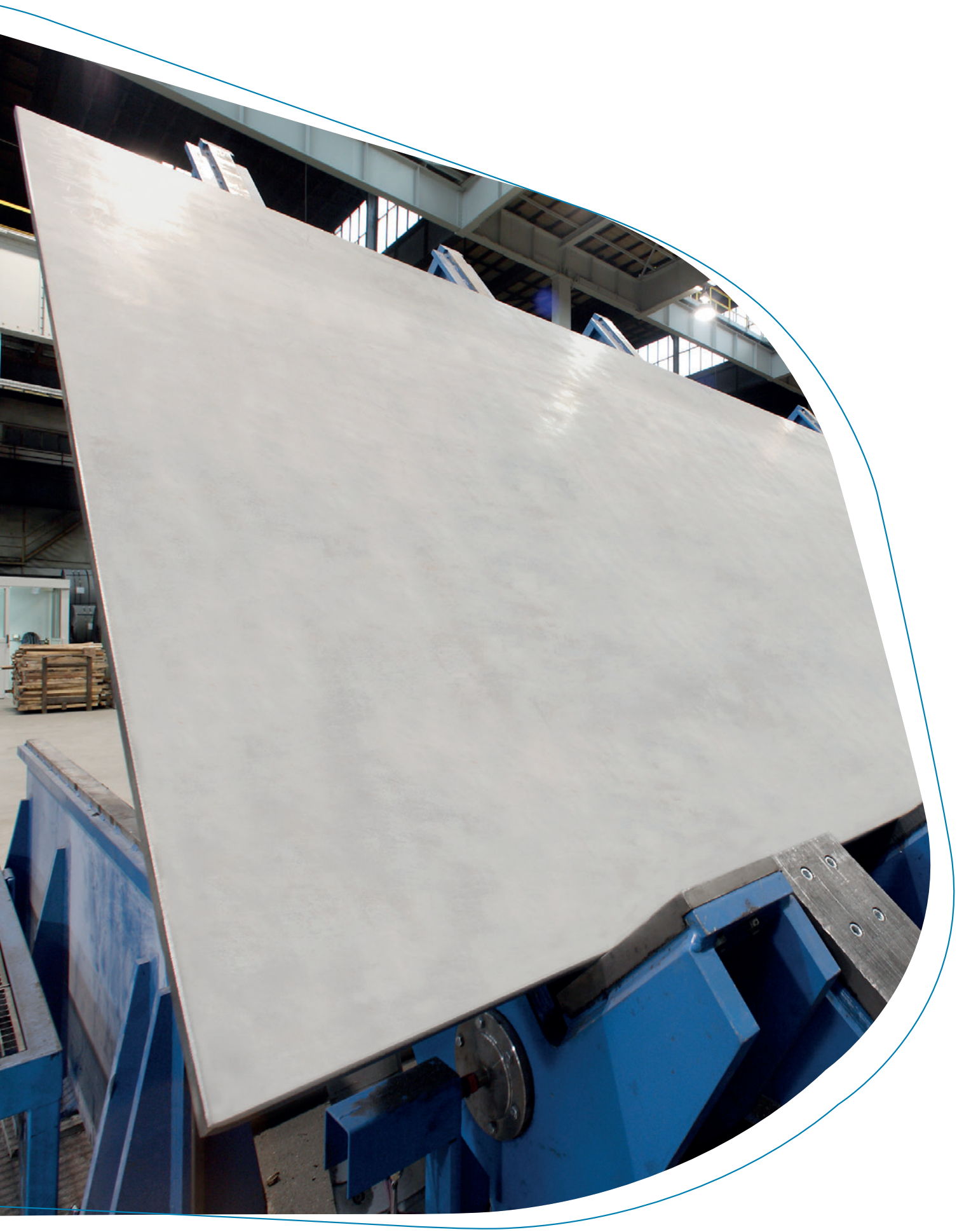

VBA170

Technical details

The following pages provide detailed information on dimensions, base materials and claddings.

voestalpine Grobblech is pleased to provide technical expertise as well as processing and welding experience gained in decades of research and development work.

- Dimensions
- Base materials
- Claddings
- Processing
- Welding



Dimensions

Depending on the type of clad material we can provide various dimensions. The clad materials mainly used are ferritic and austenitic stainless steels, nickel and nickel-based alloys, copper alloys.

■ **Clad material:**
ferritic and austenitic stainless steel

Total thickness		6 - 150 mm
Clad thickness		1.5 - 10 mm
Width		max. 3,800 mm
Length		max. 15,000 mm
	water quenched: max. 12,400 mm [1]	
Weight per plate	min. 2 t	max. 20 t
Area		min. 6 m²

■ **Clad material:**
copper alloys

Total thickness		6 - 65 mm
Clad thickness		1.5 - 10 mm
Width		max. 3,800 mm
Length		max. 15,000 mm
	water quenched: max. 12,400 mm [1]	
Weight per plate	min. 2 t	max. 20 t
Area		min. 6 m²

■ **Clad material:**
nickel alloys 625, 825

Total thickness		6 - 120 mm
Clad thickness		1.5 - 10 mm
Width		max. 3,800 mm
Length	water quenched: max. 12,400 mm [1]	
Weight per plate	min. 2 t	max. 14 t
Area		min. 6 m²

[1] Further dimensions upon request

Base materials

The base materials for roll-bonded clad plates are made of slabs cast at voestalpine steel mill on-site in Linz.

We mainly use
- Structural steels
- Pressure vessel steels
- Linepipe steels

Depending on the requirements of the respective standards and customer specifications as well as on the required corrosion resistance of the cladding materials, we provide the following delivery conditions:
- As rolled with simulated testing
- Normalizing rolled
- Normalized (furnace)
- Normalized and tempered
- Quenched and tempered
- Thermomechanically rolled and accelerated cooled (TMCP)

On the right you will find a summary of the most applicable base materials for roll-bonded clad plates. Other base materials on request. The indicated chemical and mechanical data refer to the smallest thickness group.

Base materials: Structural steels and pressure vessel steels
according to EN 10025-2, EN 10028-2 and EN 10028-3

Standard	Steel grade	C[1] max.	Si max.	Mn max.
EN 10025-2	S235JR	0.17	–	1.40
	S355JR	0.24	0.55	1.60
EN 10028-2	P235GH	0.16	0.35	0.60 - 1.20
	P265GH	0.20	0.40	0.80 - 1.40
	P295GH	0.08 - 0.20	0.40	0.90 - 1.50
	P355GH	0.10 - 0.22	0.60	1.10 - 1.70
	16Mo3	0.12 - 0.20	0.35	0.40 - 0.90
	20MnMoNi4-5	0.15 - 0.23	0.40	1.00 - 1.50
	13CrMo4-5	0.08 - 0.18	0.35	0.40 - 1.00
	10CrMo9-10	0.08 - 0.14	0.50	0.40 - 0.80
	12CrMo9-10	0.10 - 0.15	0.30	0.30 - 0.80
	13CrMoV9-10	0.11 - 0.15	0.10	0.30 - 0.60
EN 10028-3	P275 NH	0.16	0.40	0.80 - 1.50
	P275 NL1	0.16	0.40	0.80 - 1.50
	P275 NL2	0.16	0.40	0.80 - 1.50
	P355 NH	0.18	0.50	1.10 - 1.70
	P355 NL1	0.18	0.50	1.10 - 1.70
	P355 NL2	0.18	0.50	1.10 - 1.70
	P460 NH	0.20	0.60	1.10 - 1.70
	P460 NL1	0.20	0.60	1.10 - 1.70
	P460 NL2	0.20	0.60	1.10 - 1.70

Chemical composition (heat analysis) %					Mechanical properties		
P max.	S max.	Cr max.	Ni max.	Mo max.	Yield strength[1] min. [MPa]	Tensile strength[1] [MPa]	Comparable ASTM-steel grade
0.035	0.035	–	–	–	235	360 - 510	–
0.035	0.035	–	–	–	355	510 - 680	–
0.025	0.010	0.30	0.30	0.08	235	360 - 480	A285 GradeC
0.025	0.010	0.30	0.30	0.08	265	410 - 530	A516 Grade60
0.025	0.010	0.30	0.30	0.08	295	460 - 580	A516 Grade65
0.025	0.010	0.30	0.30	0.08	355	510 - 650	A516 Grade70
0.025	0.010	0.30	0.30	0.25 - 0.35	275	440 - 590	–
0.020	0.010	0.20	0.40 - 0.80	0.45 - 0.60	470	590 - 750	A533 Type B Class2
0.025	0.010	0.70 - 1.15	–	0.40 - 0.60	300	450 - 600	A387 Grade12 Class2
0.020	0.010	2.00 - 2.50	–	0.90 - 1.10	310	480 - 630	–
0.015	0.010	2.00 - 2.50	0.30	0.90 - 1.10	355	540 - 690	A387 Grade22 Class2
0.015	0.005	2.00 - 2.50	0.25	0.90 - 1.10	455	600 - 780	A542 Type D Class4
0.025	0.010	0.30	0.50	0.08	275	390 - 510	A516 Gade60
0.025	0.008	0.30	0.50	0.08	275	390 - 510	A516 Gade60
0.020	0.005	0.30	0.50	0.08	275	390 - 510	A516 Gade60
0.025	0.010	0.30	0.50	0.08	355	490 - 630	A516 Grade70
0.025	0.008	0.30	0.50	0.08	355	490 - 630	A516 Grade70
0.020	0.005	0.30	0.50	0.08	355	490 - 630	A516 Grade70
0.025	0.010	0.30	0.80	0.10	460	570 - 730	A572 Grade65
0.025	0.008	0.30	0.80	0.10	460	570 - 730	A572 Grade65
0.020	0.005	0.30	0.80	0.10	460	570 - 730	A572 Grade65

1) depending on thickness

Base materials: Structural steels and pressure vessel steels

according to ASTM

Standard	Steel grade	Chemical composition (heat analysis) %			
		C[1)2)] max.	Si max.	Mn[2)] max.	P max.
ASTM	A285 GradeC	0.28	–	0.90	0.025
	A516 Grade60	0.21	0.15 - 0.40	0.60 - 0.90	0.035
	A516 Grade65	0.24	0.15 - 0.40	0.85 - 1.20	0.035
	A516 Grade70	0.27	0.15 - 0.40	0.85 - 1.20	0.035
	A572 Grade65 Type 1	0.23	0.40	1.65	0.040
	A 204 Type A	0.18	0.15 - 0.40	0.90	0.025
	A 204 Type B	0.20	0.15 - 0.40	0.90	0.025
	A 302 Type B	0.20	0.15 - 0.40	1.15 - 1.50	0.025
	A 533 Type B Class1	0.25	0.15 - 0.40	1.15 - 1.50	0.025
	A533 Type B Class2	0.25	0.15 - 0.40	1.15 - 1.50	0.025
	A387 Grade11 Class2	0.05 - 0.17	0.50 - 0.80	0.40 - 0.65	0.025
	A387 Grade12 Class2	0.05 - 0.17	0.15 - 0.40	0.40 - 0.65	0.025
	A387 Grade22 Class2	0.05 - 0.15	0.50	0.30 - 0.60	0.025
	A 542 Type D Class4	0.11 - 0.15	0.10	0.30 - 0.60	0.015
	A841 Grad A Class1	0.20	0.15 - 0.50	0.70 - 1.60	0.030

Base materials: Fitting steels and linepipe steels

according to ASTM, API 5L and DNV OS-F101

Standard	Steel grade	Chemical composition (heat analysis) %				
		C[1)2)] max.	Si max.	Mn[2)] max.	P max.	S max.
ASTM	A106 GradeB	0.30	0.10	0.29 - 1.06	0.035	0.035
	A672 GradeC60	0.21	0.15 - 0.40	0.60 - 0.90	0.035	0.035
	A672 GradeC70	0.27	0.15 - 0.40	0.85 - 1.20	0.035	0.035
ASTM A860	WPHY 42 WPHY 52 WPHY 60 WPHY 65	0.20	0.15 - 0.40	1.00 - 1.45	0.030	0.010
API 5L	GradeB – PSL2 X52 – PSL2 X60 – PSL2 X65 – PSL2	0.22 0.22 0.22 0.22	– – – –	1.20 1.40 1.40 1.65	0.025 0.025 0.025 0.025	0.015 0.015 0.015 0.015
DNV OS-F101	SAWL 245 SAWL 360 SAWL 415 SAWL 450	0.14 0.12 0.12 0.12	0.40 0.45 0.45 0.45	1.35 1.65 1.65 1.65	0.020 0.020 0.020 0.020	0.010 0.010 0.010 0.010

				Mechanical properties		
S max.	Cr max.	Ni max.	Mo max.	Yield strength[1] min. [MPa]	Tensile strength[1] [MPa]	Comparable steel grade of EN 10028
0.025	–	–	–	205	380 - 515	P235GH
0.035	–	–	–	220	415 - 550	P275
0.035	–	–	–	240	450 - 585	–
0.035	–	–	–	260	485 - 620	P355
0.050	–	–	–	450	≥ 550	P460
0.025	–	–	0.45 - 0.60	255	450 - 585	–
0.025	–	–	0.45 - 0.60	275	485 - 620	–
0.025	–	–	0.45 - 0.60	345	550 - 690	–
0.025	–	0.40 - 0.70	0.45 - 0.60	345	550 - 690	–
0.025	–	0.40 - 0.70	0.45 - 0.60	485	620 - 795	20MnMoNi4-5
0.025	1.00 - 1.50	–	0.45 - 0.65	310	515 - 690	–
0.025	0.80 - 1.15	–	0.45 - 0.60	275	450 - 585	13CrMo4-5
0.025	2.00 - 2.50	–	0.90 - 1.10	310	515 - 690	12CrMo9-10
0.010	2.00 - 2.50	0.25	0.90 - 1.10	380	585 - 760	13CrMoV9-10
0.030	0.25	0.25	0.08	345	485 - 620	P355

1) depending on thickness
2) if C-content is reduced, Mn-content may be increased

					Mechanical properties		
Cr max.	Ni max.	Cu max.	Mo max.	V max.	Yield strength[1] min. [MPa]	Tensile strength[1] [MPa]	Comparable steel grade of ASTM / DNV / API
0.40	0.40	0.40	0.15	0.08	240	≥ 415	ASTM A516 Grade65
–	–	–	–	–	220	415 - 550	ASTM A516 Grade60
–	–	–	–	–	260	485 - 620	ASTM A516 Grade70
0.30	0.50	0.35	0.25	0.10	290 360 415 450	415 - 585 455 - 625 515 - 690 530 - 705	–
– – – –	– – – –	– – – –	– – – –	– – – –	241 - 448 359 - 531 414 - 565 448 - 600	414 - 758 455 - 758 517 - 758 531 - 758	DNV SAWL 245 DNV SAWL 360 DNV SAWL 415 DNV SAWL 450
0.30 0.50 0.50 0.50	0.30 0.50 0.50 0.50	0.35 0.50 0.50 0.50	0.10 0.10 0.50 0.50	– 0.05 0.08 0.10	245 360 415 450	370 460 520 535	API 5L GradeB API 5L X52 APL 5L X60 API 5L X65

1) depending on thickness
2) if C-content is reduced, Mn-content may be increased

Claddings

The clad materials for the roll-bonded clad plates are supplied by leading manufacturers as slabs or plates.

We mainly use

- Ferritic and austenitic stainless steels and heat-resistant steels
- Nickel and nickel-based alloys
- Copper and copper-alloys

On the right you will find a summary of the most frequently used clad materials for roll-bonded clad plates. Other clad materials on request.

Claddings: Stainless steels and heat-resistant steels

Standard	EN material number		C max.	Si max.
EN 10088	1.4000	X6Cr13	0.08	1.0
	1.4301	X5CrNi18-10	0.07	1.0
	1.4306	X2CrNi19-11	0.03	1.0
	1.4541	X6CrNiTi18-10	0.08	1.0
	1.4550	X6CrNiNb18-10	0.08	1.0
	1.4401	X5CrNiMo17-12- 2	0.07	1.0
	1.4404	X2CrNiMo17-12-2	0.03	1.0
	1.4571	X6CrNiMoTi17-12-2	0.08	1.0
	1.4432	X2CrNiMo17-12-3	0.03	1.0
	1.4435	X3CrNiMo18-14-3	0.03	1.0
	1.4429	X2CrNiMoN17-13-3	0.03	1.0
	1.4438	X2CrNiMo18-15-4	0.03	1.0
	1.4439	X2CrNiMoN17-13-5	0.03	1.0
SEW 470	1.4828	X 15 CrNiSi 20 12	0.20	1.5 - 2.5
Standard	**UNS number**		**C max.**	**Si max.**
ASTM A240 and ASME SA240	S41008	410S	0.08	1.00
	S30400	304	0.07	0.75
	S30403	304L	0.03	0.75
	S32100	321	0.08	0.75
	S34700	347	0.08	0.75
	S31600	316	0.08	0.75
	S31603	316L	0.03	0.75
		316L Mod Mo ≥ 2.5	0.03	0.75
	S31635	316Ti	0.08	0.75
	S31653	316LN	0.03	0.75
	–	316LN Mod Mo ≥ 2.5	0.03	0.75
	S31703	317L	0.03	0.75
	S31726	317LMN	0.03	0.75

Chemical composition (heat analysis) % (extract)								
Mn max.	P max.	S max.	Cr	Ni	Mo	Others	Mean pitting resistance equivalent number (PREN) Cr+3.3Mo+16N [%]	Comparable ASTM A240 / ASME SA240 type
1.0	0.040	0.030	12.0 - 14.0	–	–	–	–	410S
2.0	0.045	0.030	17.0 - 19.5	8.0 - 10.5	–	N ≤ 0.10	–	304
2.0	0.045	0.030	18.0 - 20.0	10.0 - 12.0	–	N ≤ 0.10	–	304L
2.0	0.045	0.030	17.0 - 19.0	9.0 - 12.0	–	5xC < Ti ≤ 0.70	–	321
2.0	0.045	0.015	17.0 - 19.0	9.0 - 12.0	–	10xC < Nb ≤ 1.00	–	347
2.0	0.045	0.030	16.5 - 18.5	10.0 - 13.0	2.0 - 2.5	N ≤ 0.10	25	316
2.0	0.045	0.030	16.5 - 18.5	10.0 - 13.0	2.0 - 2.5	N ≤ 0.10	25	316L
2.0	0.045	0.030	16.5 - 18.5	10.5 - 13.5	2.0 - 2.5	5xC < Ti ≤ 0.70	25	316Ti
2.0	0.045	0.030	16.5 - 18.5	10.5 - 13.0	2.5 - 3.0	N ≤ 0.10	27	316L Mod Mo ≥ 2.5
2.0	0.045	0.030	17.0 - 19.0	12.5 - 15.0	2.5 - 3.0	N ≤ 0.10	28	316L Mod Mo ≥ 2.5
2.0	0.045	0.015	16.5 - 18.5	11.0 - 14.0	2.5 - 3.0	N = 0.12 - 0.22	29	316LN Mod Mo ≥ 2.5
2.0	0.045	0.030	17.5 - 19.5	13.0 - 16.0	3.0 - 4.0	N ≤ 0.10	31	317L
2.0	0.045	0.015	16.5 - 18.5	12.5 - 14.5	4.0 - 5.0	N 0.12 - 0.22	35	317LMN
2.0	0.045	0.015	19.0 - 21.0	11.0 - 13.0	–	N ≤ 0.10	–	–

Chemical composition (heat analysis) % (extract)								
Mn max.	P max.	S max.	Cr	Ni	Mo	Others	Mean pitting resistance equivalent number (PREN) Cr+3.3Mo+16N [%]	Comparable grade of EN 10088
1.0	0.040	0.030	11.5 - 13.5	max. 0.60	–	–	–	1.4000
2.0	0.045	0.030	17.5 - 19.5	8.0 - 10.5	–	N ≤ 0.10	–	1.4301
2.0	0.045	0.030	17.5 - 19.5	8.0 - 12.0	–	N ≤ 0.10	–	1.4306
2.0	0.045	0.030	17.0 - 19.0	9.0 - 12.0	–	N ≤ 0.10 5x(C+N) < Ti ≤ 0.70	–	1.4541
2.0	0.045	0.030	17.0 - 19.0	9.0 - 13.0	–	10xC < Nb ≤ 1.00	–	1.4550
2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.0 - 3.0	N ≤ 0.10	25	1.4401
2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.0 - 3.0	N ≤ 0.10	25	1.4404
2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.5 - 3.0	N ≤ 0.10	27	1.4432/1.4435
2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.0 - 3.0	N ≤ 0.10 5x(C+N) < Ti ≤ 0.70	25	1.4571
2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.0 - 3.0	N = 0.10 - 0.16	27	–
2.0	0.045	0.030	16.0 - 18.0	10.0 - 14.0	2.5 - 3.0	N = 0.10 - 0.16	29	1.4429
2.0	0.045	0.030	18.0 - 20.0	11.0 - 15.0	3.0 - 4.0	N ≤ 0.10	31	1.4438
2.0	0.045	0.030	17.0 - 20.0	13.5 - 17.5	4.0 - 5.0	N = 0.10 - 0.20	35	1.4439

Claddings: Special steels, non-ferrous metals and alloys

ASTM	Type	Chemical composition (heat analysis) % (extract)					
		C max.	Si max.	Mn max.	P max.	S max.	Cr
B 409 UNS N08800	Alloy 800	0.10	1.00	1.5	–	0.015	19.0 - 23.0
A 240/A 240M UNS N08904	Alloy 904 L	0.02	1.00	2.0	0.045	0.035	19.0 - 23.0
B 709 UNS N08028	Alloy 28	0.03	1.00	2.5	0.030	0.030	26.0 - 28.0
B 677 UNS N08926	Alloy 926	0.02	0.50	2.0	0.030	0.010	19.0 - 21.0
B 463 UNS N08020	Alloy 20	0.07	1.00	2.0	0.045	0.035	19.0 - 21.0
B 463 UNS N08020	Alloy 20	0.07	1.00	2.0	0.045	0.035	19.0 - 21.0
B 424 UNS N08825	Alloy 825	0.05	0.50	1.0	–	0.030	19.5 - 23.5
B 443 UNS N06625	Alloy 625	0.10	0.50	0.5	0.015	.015	20.0 - 23.0
B 575 UNS N06022	Alloy C 22	0.015	0.08	0.5	0.020	0.020	20.0 - 22.5
B 575 UNS N06455	Alloy C 4	0.015	0.08	1.0	0.040	0.030	14.0 - 18.0
B 575 UNS N10276	Alloy C 276	0.01	0.08	1.0	0.040	0.030	14.5 - 16.5
B 575 UNS N06059	Alloy 59	0.01	0.10	0.5	0.015	0.010	22.0 - 24.0
B 333 UNS N10665	Alloy B 2	0.02	0.10	1.0	0.040	0.030	1.0
B 168 UNS N06600	Alloy 600	0.15	0.50	1.0	–	0.015	14.0 - 17.0
B 127 UNS N04400	Alloy 400	0.30	0.50	2.0	–	0.024	–
B 162 UNS N02200	Alloy 200	0.15	0.35	0.35	–	0.010	–
B 162 UNS N02201	Alloy 201	0.02	0.35	0.35	–	0.010	–
–	–	–	–	–	0.001 - 0.005	–	–
B 152 UNS C12200	–	–	–	–	0.015 - 0.040	–	–
B 171 UNS C70600	Alloy CuNi 90/10	–	–	1.0	–	–	–
B 171 UNS C71500	Alloy CuNi 70/30	0.05	–	1.0	–	–	–

				Comparable grades		
Ni	Mo	Others	Mean pitting resistance equivalent number (PREN) Cr+3.3Mo+16N [%]	EN material number	EN / DIN / SEW	VdTÜV material sheet
30.0 - 35.0	–	Al = 0.15 - 0.60 Ti = 0.15 - 0.60 Cu ≤ 1.5, Fe ≥ 39.5	–	1.4876	SEW 470	412
23.0 - 28.0	4.0 - 5.0	Cu = 1.0 - 2.0	36	1.4539	EN 10088	421
29.5 - 32.5	3.0 - 4.0	Cu = 0.60 - 1.40	39	1.4563		–
24.0 - 26.0	6.0 - 7.0	Cu = 0.50 - 1.50 N = 0.15 - 0.25	44	1.4529		502
32.0 - 38.0	2.0 - 3.0	Cu = 3.0 - 4.0 8xC < (Nb+Ta) ≤ 1.0	28	2.4660	DIN 17744	–
32.0 - 38.0	2.0 - 3.0	Cu = 3.0 - 4.0 8xC < (Nb+Ta) < 1.0	28	2.4660	DIN 17744	–
38.0 - 46.0	2.5 - 3.5	Cu = 1.5–3.0 Ti = 0.60–1.20 Fe > 22.0, Al < 0.2	31	2.4858	DIN 17744	432
> 58.0	8.0 - 10.0	Fe < 5.0, (Co < 1.0) Nb = 3.15 - 4.15 Al < 0.40, Ti < 0.40	51	2.4856	DIN 17744	499
rest	12.5 - 14.5	Fe = 2.0 - 6.0 W = 2.5 - 3.5 V < 0.35, Co < 2.50	66	2.4602	DIN 17744	479
rest	14.0 - 17.0	Fe < 3.0 Ti < 0.70 Co < 2.0	67	2.4610	DIN 17744	424
rest	15.0 - 17.0	W = 3.0 - 4.5 Fe = 4.0 - 7.0 Co < 2.5, V < 0.35	68	2.4819	DIN 17744	400
rest	15.0 - 16.5	Al = 0.1 - 0.4 Fe < 1.5, Co < 0.3 Cu < 0.5	75	2.4605	DIN 17744	505
rest	26.0 - 30.0	Fe < 2.0 Co < 1.00	–	2.4617	DIN 17744	436
> 72.0	–	Fe = 6.0 - 10.0 Cu < 0.50	–	2.4816	DIN 17742	305
> 63.0	–	Cu = 28.0 - 34.0 Fe < 2.5	–	2.4360	DIN 17743	263
> 99.00	–	Fe < 0.4 Cu < 0.25	–	2.4066	DIN 17740	–
> 99.00	–	Fe < 0.4 Cu < 0.25	–	2.4068		345
–	–	Cu > 99.95	–	2.0070	DIN 1787	–
–	–	Cu > 99.90	–	CW 024 A	EN 1652	–
9.0 - 11.0	–	Fe = 1.0 - 1.8, Cu rest, Zn < 1.0, Pb < 0.05	–	CW 352 H		420
29.0 - 33.0	–	Fe = 0.40 - 1.0, Cu rest Zn < 1.0, Pb < 0.05	–	CW 354 H		–

Processing

voestalpine Grobblech is pleased to provide expertise and technical experience in cutting, cold forming and hot forming, gained over decades of research and development work.

Cutting

Roll-bonded clad plates are best cut using plasma torches. This cutting process provides clean cut edges, which are prepared for subsequent welding by simply removing the oxide skin.
Note: The plasma cut is always performed from the clad side.

It is also possible to use oxy-gas cutting (starting from the base material side) or oxy-gas cutting with flux addition (starting from the clad side). However, this is rarely done because it produces irregular cut edges. Thin clad plates can be shear cut (cladding material on top) without problems. Cutting is always performed ensuring sharp blades, exact setting of the cutting clearence and optimum bankholder force.

Cold forming

Cold forming of roll-bonded clad plates is possible by bending, pressing, dishing and rolling. Clean surfaces of the cladding and tools are of great importance in all forming processes. Roll-bonded clad plates show excellent forming behavior.

The material-specific properties of the clad material must be taken into account. Specific information and recommendations on cold forming and heat treatment of stainless steel, non-ferrous metals and alloys can be found in the corresponding material data sheets of these clad materials provided by the manufacturer of those materials.

As an example, here are the processing recommendations when using alloy 625 as clad material:
The clad plate should be in annealed condition before cold forming. Due to high strain hardening during cold working intermediate annealing is recommended for strong cold forming. A final soft annealing has to be applied for cold forming above 10 %.

Hot forming

Roll-bonded clad plates are formed in accordance with accepted technologies and by taking into consideration the cladding material. The surfaces of the cladding materials must be free of contaminations like grease, oil, marking colors etc. in order to prevent carburization. It is very important to obtain an atmosphere with low sulfur content.

In some cases heat treatment is required after hot forming. High-alloy claddings can only achieve their optimum corrosion resistance by means of special temperature controls.
Therefore, voestalpine Grobblech should be contacted early in the beginning stages of component design. To avoid corrosion, the surface of the cladding material must be cleaned after the last processing step. Oxide skins, annealing colors, welding spatters, any scratches resulting from ferrous materials, marks, rust from external sources etc. must be removed.

Welding

The instructions in this brochure are of a general nature. For detailed information, experienced welding engineers are at your disposal.

Welding processes

As a rule the base materials are welded by applying shielded metal arc welding (SMAW), gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), flux core arc welding (FCAW), submerged arc welding (SAW), submerged arc strip cladding (SASC) and electro slag strip cladding (ESSC).

The following welding processes for cladding materials are used, where base metal are less diluted, such as

- SMAW
- GTAW, pulse GTAW
- FCAW
- Electro slag strip cladding (ESSC)
- Pulse GMAW
- Submerged arc strip cladding (SASC)

Filler metals

The filler metals for welding the base materials of clad plates are the same as for non-clad plates. The recommended filler metals for the claddings of the tables on pages 26/27 and 28/29 are indicated in the tables on pages 33 and 34/35. Selections are made after considering the following aspects:

- If possible, the first layer should be welded with over-alloyed fillers, in order to approximate to the composition of the cladding during mixing with the base material.

- For 13 % Cr steel claddings, not only the buffer is welded with an over-alloyed austenitic electrode, type 23 12 L, but frequently the cover pass as well. If standard fillers of 19/9-types are used, there is a risk of martensite formation at high dilution of 13 % Cr steel. A buffer with electrode type 23 12 L is also recommended for cover passes with 13 % Cr weld metals. When applying ESSC, several solutions exist to clad with single layer (without buffer layer).

- In contrast to weld metal that is similar in composition to the base material, low-carbon 18-8 CrNi and CrNiMo steels do not become susceptible to intergranular corrosion by stress-relief annealing. Thus we recommend Nb-stabilized-carbon weld metal for subsequent stress-relief annealing.

- For austenitic steels and nickel alloys with more than 3.0 % Mo, the recommended filler materials for the filler and cover passes should be over-alloyed by a factor of 1.3 with respect to Mo. This is done to reduce the risk of pitting corrosion, where the pren is decisive. In every cast material and especially in the non-solution-annealed weld metal, Mo is more segregated than in the cladding. Therefore Mo-depleted zones occur which have only 70-80 % of the average Mo-content.

- Soldering brittleness may occur when welding Cu, CuNi 90/10 and CuNi 70/30 onto steel. Therefore we recommend a buffer with alloy 400 (table on page 34/35).

Recommended filler metals for the welding of stainless or heat-resistant claddings

according to EN ISO 3581-A, EN ISO 14343-A and EN ISO 17633-A
as well as AWS A 5.4, A 5.9 and A 5.22

Cladding		Filler metal type[1]					
EN material number	ASTM A 240 type	multi-pass (SMAW)[2]				single-pass ESSC (SASC) strip[3]	
		buffer		subsequent passes			
		EN ISO	AWS	EN ISO	AWS	EN ISO	AWS
1.4000	410S	23 12 L	309L	19 9 Nb 13	347 410	22 11 L 13L oder 17L	– 410L oder 430L
1.4301	304	23 12 L	309L	19 9 L	308L	23 12 L 22 11 L 19 9 L	309L – 308L
1.4306	304L			19 9 L 19 9 Nb	308L 347[4]		
1.4541	321			19 9 Nb 19 9 Nb	347 347[4]	23 12 Nb 21 11 LNb 19 9 Nb	309LNb – 347
1.4550	347						
1.4401	316	23 12 2 L	309L Mo	19 12 3 L[5] 19 12 3 Nb[5]	316L[5] 318[5]	19 12 3 L 21 13 3 L	316L –
1.4404	316L						
1.4571	316Ti						
1.4432	316L Mo ≧ 2.5			18 16 5 L	317L mod.	19 13 4 L	317L
1.4435	316 Mo ≧ 2.5						
1.4429	316LN Mo ≧ 2.5						
1.4438	317L	23 12 L	309L	18 16 5 L	317L mod.	Ni6625(NiCr22Mo9Nb) (Alloy 625)	NiCrMo 8 (Alloy 625)
1.4439	–			20 25 6 Cu L	385 mod.		
1.4828	305	18 8 Mn	307 mod.	22 12	309	22 11 L	–

[1] Some of the filler metals are not included in the standards, but available on the market.
[2] For GTAW, GMAW or FCAW welding, types of similar composition are used.
[3] The selection of the strip depends on the welding process (ESSC, SASC), the flux, the base material, the required bead thickness etc. We would be glad to provide you with a comprehensive consultation.
[4] To be applied for stress-relief annealing.
[5] If stress-relief annealing is applied, please contact us.

Recommended filler metals for the welding of clad materials made of special steels, non-ferrous metals and alloys

according to EN ISO 18274, EN ISO 14640 and/or EN ISO 3581-A, EN ISO 14343-A, EN ISO 17633-A, EN ISO 14172-A, EN ISO 12153 as well as AWS A 5.4, A 5.7, A 5.9, A 5.11, A 5.14, A 5.16, and A 5.22

Cladding		Filler metal type	
Alloy type	EN material number	multi-pass (GTAW, GMAW,FCAW)	
		buffer	buffer
		EN ISO	AWS
Alloy 800	1.4876	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
Alloy 904L	1.4539	23 12 L	309L
Alloy 28	1.4563	23 12 L	309L
Alloy 926	1.4529	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
Alloy 20	2.4660	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
Alloy 825	2.4858	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
Alloy 625	2.4856	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
Alloy C22	2.4602	Ni 60 22 (NiCr21Mo13W3)	NiCrMo-10
Alloy C4	2.4610	Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-7
Alloy C-276	2.4819	Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-7
Alloy 59	2.4605	Ni 60 59 (NiCr23Mo16)	NiCrMo-13
Alloy B2	2.4617	–	–
Alloy 600	2.4816	Ni 60 82 (NiCr20Mn3Nb)	NiCr-3
Alloy 400	2.4360	Ni 40 60 (NiCu30Mn3Ti)	NiCu-7
Alloy 200	2.4066	Ni 20 61 (NiTi3)	Ni-1
Alloy 201	2.4068		
SE-Cu	2.0070	Ni 40 60 (NiCu30Mn3Ti)	NiCu-7
SF-Cu	CW024A		
Alloy CuNi 90/10	CW352H		
Alloy CuNi 70/30	CW354H		

Filler metal type		single-pass ESSC (SASC) strip	
multi-pass (GTAW, GMAW,FCAW)			
subsequent passes			
EN ISO	AWS	EN ISO	AWS
Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
20 25 5 CuL	385	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
27 31 4 CuL	383	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3
Ni 66 25 (NiCr22Mo9Nb)	NiCrMo-3	Ni 60 59 (NiCr23Mo16)	NiCrMo-13
Ni 60 22 (NiCrMo13W3)	NiCrMo-10	Ni 60 22 (NiCr21Mo13Fe4W3)	NiCrMo-10
Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-7	Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-7
Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-7	Ni 62 76 (NiMo16Cr15Fe6W4)	NiCrMo-4
Ni 60 59 (NiCr23Mo16)	NiCrMo-13	Ni 60 59 (NiCr23Mo16)	NiCrMo-13
–	–	Ni 64 55 (NiCr16Mo16Ti)	NiCrMo-7
Ni 60 82 (NiCr20Mn3Nb)	NiCr-3	Ni 60 82 (NiCr20Mn3Nb)	NiCr-3
Ni 40 60 (NiCu30Mn3Ti)	NiCu-7	Ni 40 60 (NiCu30Mn3Ti)	NiCu-7
Ni 20 61 (NiTi3)	Ni-1	Ni 20 61 (NiTi3)	Ni-1
Ni 40 60 (NiCu30Mn3Ti)	NiCu-7	Welding of Cu and Cu-Alloys onto carbon steel without buffer layer is not recommended.	

[1] Over-alloyed, for maximum corrosion resistance – e.g. ERNiCrMo-13

[2] Matching, at least two passes are required

[3] for higher electrical conductivity

Weld shapes

Preparation and execution of welding must be performed in such a way that the weld metal for the base material does not fuse the cladding. This prevents the formation of brittle or hot-crack sensitive weld metal. During pre-processing of the weld edges the actual thickness of the cladding needs to be taken into consideration. Any filling of the base material weld should be executed from the base material side, if possible, in order to avoid contamination of the cladding material.

Butt welds

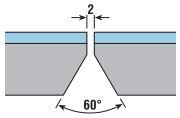
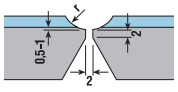
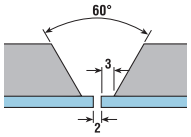
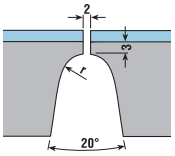
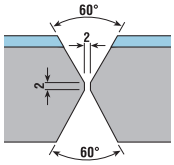
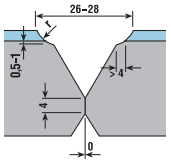
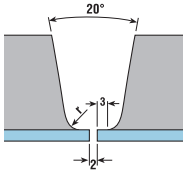
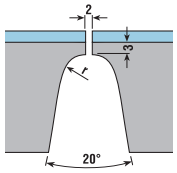
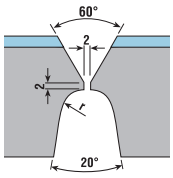
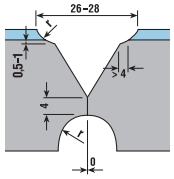
The weld shapes shown on page 37 apply to nearly all clad plates.

Fillet welds

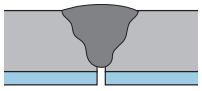
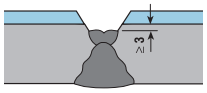
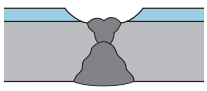
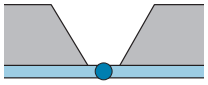
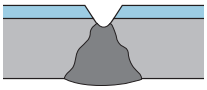
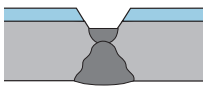
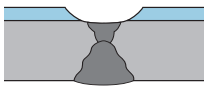
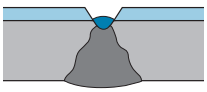
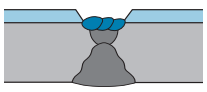
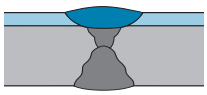
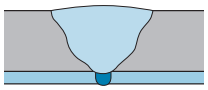
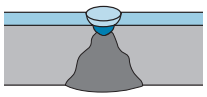
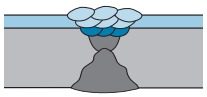
The bonding of the cladding in our roll-bonded clad plates is so strong, even considerably over-dimensioned fillet welds do not cause any detachment of the cladding material. However, the standards for the ultrasonic testing of clad plates allow certain bonding defects. When welding fillet welds onto the cladding material, the plate must be carefully checked for proper bonding by ultrasonic testing in the area of the weld before and after the welding operation. Removal of the cladding with subsequent weld cladding to prepare vertical connection is only required in areas where bonding defects have been found in the ultrasonic test. Any melting through the cladding has to be compensated for by a corresponding over-alloyed filler metal.

Butt seam welding

Recommended weld shapes and welding sequences.

Thickness [mm]	WELD PREPARATION [1] access from both sides 2)	3)	4)	access from one side
5 - 19	 (BM: GMAW)		 (BM: GTAW root)	
20 - 30	 (BM: GMAW)	 (BM: SMAW)	 (BM: SAW)	
> 30	 (BM: GMAW)	 (BM: SMAW)	 (BM: SAW)	radius r depending on the process [1] BM... base material

WELDING SEQUENCES

Welding process for cladding	SMAW, GTAW, FCAW	SMAW, GMAW, FCAW	ESSC/SASC (SAW) strip	GTAW root
Base material welding				
Grinding				1. GTAW welding of the cladding
Buffer layer welding				
Welding of the filler and cover layers				2. Welding of the base material with filler metal for mixed composition

[1] The root gap, the thickness of the root face, the radii and the weld preparation angle depend on the welding processes used. The drawings show examples of dimensions and appropriate processes for welding of the base material. Favourable radii are: r = 8 mm for the base material; r = 4 mm for the clad material and welding with wire electrodes, r = 8 mm with strip electrodes.

[2] Preferable weld shapes for all welding positions and high-alloy claddings.

[3] Weld shape for thicker plates; SAW for base material.

[4] Weld shape if the total base material thickness is included in the calculation of the strength. The welded cladding should melt down the base material as little as possible. Mainly applied for manual MAW or ESSC/SASC (SAW) strip.

Welding execution

Cleaning

The welding of the cladding layer requires the same cleanliness as when working with solid materials of a similar composition. Consequently, chippers, brushes etc., of stainless steel are to be used. In the case of Ni and Ni-alloys, prevention of all sulfur-containing contaminations is of utmost importance. Therefore only grinding materials with sulfur-free bonding agents (synthetic resin adhesion) should be used.

Weld design

The full alloy content (or a limitation to a maximum of 5 % Fe for Ni or Alloy 400) is often only achieved in the third pass. Consequently, in most cases a weld reinforcement of 2 up to 3 mm is allowed on the side of the cladding material in order to obtain sufficient room for three passes. If a limit is set for the weld reinforcement, the first and the second pass must be heavily ground before welding is continued.

Preheating and heat control

Welding of the base material:
We recommend using EN 1011-2 for calculating the minimum preheating temperature, which depends on the chemical analysis, the thickness and the welding process employed.

Welding of the buffer:
Most of the buffers are welded using austenitic filler materials which give off very little hydrogen to the base material. According to experience, the preheating temperature may therefore be lower than calculated:

- Approx. 50 °C lower for SMAW
- Up to 100 °C lower for GMAW, GTAW, FCAW and ESSC/SASC (SAW) strip welding.

Welding of the cladding material:
An overview of the heat control during welding of the cladding material is given in the table below.

Cladding	Filler	Preheating min. °C	Interpass temp. max. °C
13 % Cr-steels	austenitic	–	200
	matching	150	250
CrNi-steels	matching	none	150
Ni and Ni-alloys	matching	none	150
Cu	matching	> 400	600
CuNi and NiCu-alloys	matching	none	150

Stress-relief annealing

Generally, stress-relief annealing of roll-bonded clad plates is only necessary as a requirement of the base material. By stress-relief annealing the properties of the cladding and the corresponding weld metal may deteriorate due to precipitation of carbides, intermetallic phases etc. Therefore, stress-relief annealing is to be avoided if possible or adjusted to the base and cladding materials. Only grinding materials with sulfur-free bonding agents (synthetic resin adhesion) should be used.

Post-treatment of the welds

Smoothening of the weld to prevent deposits (crevice corrosion), pickling to remove annealing colors or similar measures may be required, depending on the type of the cladding material and the attacking medium.

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