VDM® Alloy 22

Nicrofer 5621 hMoW

Material Data Sheet No. 4121
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VDM® Alloy 22 is a nickel-chromium-molybdenum alloy with tungsten and extremely low carbon and silicon content.

VDM® Alloy 22 is characterized by:

- Extraordinary resistance across a wide range of corrosive media under oxidizing and reducing conditions
- Particularly high resistance to crevice, pitting, and stress corrosion

Designations

Standard	Material designation
EN	2.4602 – NiCr21Mo14W
ISO	NiCr21Mo14W3
UNS	N06022

Standards

Product form	ASTM	ASME	DIN	ISO	NACE	sonstige
Sheet, plate	B 575	SB 575	17750 17744	6208 9722	MR 0103/ISO 17945 MR 0175/ISO 15156	VdTÜV 479
Strip	B 575	SB 575	17744	18274 6208	MR 0175/ISO 15156	
Rod, bar	B 574 B 564	SB 574 SB 564	17744 17752		MR 0175/ISO 15156 MR 0103/ISO 17945	VdTÜV 479
Wire			17744			DIN EN ISO 18274

Table 1 – Designations and standards

Chemical composition

	Cr	Mo	Ni	Fe	W	Co	Mn	V	Si	P	C	S
Min.	20.0	12.5	bal.	2.0	2.5							
Max.	22.5	14.5		6.0	3.5	2.5	0.50	0.35	0.08	0.025	0.015	0.02
Due to technical reasons the alloy may contain additional elements												

Table 2 – Chemical composition (%) according to ASTM B575

Physical properties

Density	Melting range	Brinell Hardness
8.7 g/m³ at 20 °C 543 lb/ft² at 68 °F	1,360 – 1,400 °C 2,470 – 2,550 °F	240

Temperature		Specific heat capacity		Thermal conductivity		Electrical resisticity	Modulus of elasticity		Coefficient of thermal expansion 20 °C (68 °F) to T	
°C	°F	$\frac{J}{kg \cdot K}$	$\frac{Btu}{lb \cdot °F}$	$\frac{W}{m \cdot K}$	$\frac{Btu \cdot in}{sq. ft \cdot h \cdot °F}$	μΩ · cm	GPa	10^3 ksi	$\frac{10^{-6}}{K}$	$\frac{10^{-6}}{°F}$
0	32	402	0.096				207	30		
20	68	406	0.097	9.4	65.2	121	206	29.9		
100	212	423	0.101	11.1	77.0	123	202	29.3	12.4	6.89
200	392	444	0.106	13.4	92.9	123	197	28.6	12.4	6.89
300	572	460	0.11	15.5	107	125	190	27.6	12.5	6.94
400	752	476	0.114	17.5	121	126	185	26.8	13.1	7.28
500	932	495	0.118	19.5	135	127	178	25.8	13.7	7.61
600	1,112	514	0.123	21.3	148	128	173	25.1	14.3	7.94
700	1,292	533	0.127	23.2	161	129	167	24.2	14.9	8.28
800	1,472						159	23.1	15.5	8.61
900	1,652						150	21.8	15.8	8.78
1,000	1,832						143	20.7	16.2	9.0

Table 3 – Typical physical properties at room and elevated temperatures

Microstructural properties

VDM® Alloy 22 has a cubic, face-centered crystal structure.

Mechanical properties

The following minimum values at room and increased temperatures apply to the solution-annealed condition for longitudinal and traverse test samples of the specified dimensions. The properties for larger dimensions must be agreed upon separately.

Temperature		Yield strength $R_{p\,0.2}$		Yield strength $R_{p\,1,0}$		Tensile strength R_m		Elongation A
°C	°F	MPa	ksi	MPa	ksi	MPa	ksi	%
20	68	310	45	335	48.6	690-950	100-138	45
100	212	270	39.2	290	42.1			
200	392	225	32.6	245	35.5			
300	300	195	28.3	215	31.2			
400	752	175	25.4	195	28.3			

Table 4 – Mechanical properties at room and elevated temperatures. Minimum values according to VdTÜV Sheet 479

Product form	Dimension		Yield strength $R_{p\,0,2}$		Yield strength $R_{p\,1,0}$		Tensile strength R_m		Elongation A
	mm	in	MPa	ksi	MPa	ksi	MPa	ksi	%
Plate	≤ 3	0.118	≥ 310	45	≥ 335	48.6	≥ 690	100	≥ 45
Coil	≤ 3	0.118	≥ 310	45	≥ 335	48.6	≥ 690	100	≥ 45
Plate	3-50	0.118-1.97	≥ 310	45	≥ 335	48.6	≥ 690	100	≥ 45
Bar	10-90	0.394-3.54	≥ 310	45	≥ 335	48.6	≥ 690	100	≥ 45

Table 5 – Mechanical properties at room temperature. Minimum values according to VdTÜV Sheet 479

ISO V-notch impact energy KV_2

Minimum value	Minimum value
20 °C (68 °F)	-196 °C (-321 °F)
120 J (88.5 ft·lbs)	96 J (22.9 ft·lbs)

1)Average value of 3 samples. Only one value may fall below the minimum average value, and by no more than 30%. The values also apply for the heat affected zones in welded joints.
2)These values only apply for normal samples according to DIN EN ISO 148-1. For undersized samples according to DIN EN ISO 148-1, the minimum values indicated for the notch impact toughness must be reduced in a manner that is linear to the sample cross-section in the gap. For undersized samples <5mm according to DIN EN ISO 148-1, the values for the individual case must be coordinated with the manufacturer separately.

Corrosion resistance

Due to the extremely low carbon and silicon concentrations, VDM® Alloy 22 has no propensity for grain boundary dispersions in hot forming or welding. This alloy can therefore be used in many chemical processes with both oxidizing and reducing media when welded. The high chrome, molybdenum, and nickel concentrations make the alloy resistant to chloride ion attacks. The tungsten concentration further increases this resistance. VDM® Alloy 22 is resistant to chlorine gas, hypochlorite, and chlorine dioxide solutions such as those that can be encountered in the cellulose industry. The alloy is characterized by excellent resistance to concentrated solutions of oxidizing salts (such as iron III and copper chloride).

Applications

VDM® Alloy 22 has a broad field of application in the chemicals and petrochemicals industry and is used for components in organic processes that contain chloride and for catalytic systems. The material is especially effective in hot, contaminated mineral acids, solutions, organic acids (such as formic acid and acetic acid) or sea water.
Other fields of application are:

- Acetic acid production
- Pharmaceuticals industry
- Fine chemicals

Fabrication and heat treatment

VDM® Alloy 22 can be easily formed both hot and cold and can also be machined

Heating

It is important that the workpieces are clean and free of any contaminations before and during heat treatment. Sulfur, phosphorus, lead and other low-melting point metals can result in material damage during the heat treatment. This type of contamination is also contained in marking and temperature-indicating paints or pens, and also in lubricating grease, oils, fuels and similar materials. The sulfur content of fuels must be as low as possible. Natural gas should contain less than 0.1 wt.-% of sulfur. Heating oil with a maximum sulfur content of 0.5 wt.-% is also suitable. Electric furnaces are preferable for their precise temperature control and a lack of contaminations from fuels. The furnace temperature should be set between neutral and slightly oxidizing and it should not change between oxidizing and reducing. The workpieces must not come into direct contact with flames.

Hot forming

The material can be hot-formed in a temperature range between 1,100 and 900 °C (2,012 °F-1,652 °F) with subsequent rapid cooling down in water or air. Heat treatment after hot forming is recommended in order to achieve optimal properties. For heating up, workpieces should be placed in a furnace that is already heated up to the target value.

Cold forming

VDM® Alloy 22 has higher work hardening rate than other austenitic stainless steels. This should be taken into account when selecting forming equipment. The workpiece should be in the solution-annealed condition. Intermediate annealing is necessary for major cold forming work. For cold forming above 15%, new solution annealing must be conducted.

Heat treatment

Solution annealing should take place at temperatures between 1,105 and 1,135 °C (2,021-2,075 °F).
Cooling down should be accelerated with water to achieve optimum corrosion properties. Fast air cooling can also be carried out at thicknesses of less than approx. 1.5 mm. For strips as the product form, the heat treatment can be performed in a continuous furnace at a speed and temperature that is adapted to the strip thickness. In each heat treatment, the aforementioned cleanliness requirements must be observed.

Descaling and pickling

Oxides of VDM® Alloy 22 and heat tint in the area around welds adhere more strongly than in stainless steels. Grinding using extremely fine abrasive belts or grinding discs is recommended. It is imperative that grinding burns be avoided. Before pickling in nitric-hydrofluoric acid, the oxide layers should be destroyed by abrasive blasting or fine grinding, or pre-treated in salt baths. The pickling baths used should be carefully monitored with regard to concentration and temper- ature.

Machining

VDM® Alloy 22 should be machined in the solution-annealed condition. Because of the considerably elevated tendency toward work hardening in comparison with low-alloy austenitic stainless steels, a low cutting speed and a feed level that is not too high should be selected and the cutting tool should be engaged at all times. An adequate chip depth is important in order to cut below the previously formed strain-hardened zone. An optimal heat dissipation by using large quantities of suitable, preferably aqueous, cold forming lubricants has considerable influence on a stable machining process.

Welding information

When welding nickel alloys and special stainless steels, the following information should be taken into account:

Safety

The generally applicable safety recommendations, especially for avoiding dust and smoke exposure must be observed.

Workplace

A separately located workplace, which is specifically separated from areas in which C-steel is being processed, must be provided. Maximum cleanliness is required, and drafts should be avoided during gas-shielded welding.

Auxiliary equipment and clothing

Clean fine leather gloves and clean working clothes must be used.

Tools and machines

Tools that have been used for other materials may not be used for nickel alloys and stainless steels. Only stainless steel brushes may be used. Processing and treatment machines such as shears, punches or rollers must be fitted (felt, cardboard, films) so that the workpiece surfaces cannot be damaged by the pressing in of iron particles through such equipment, as this can lead to corrosion.

Edge preparation

Welding seam preparation should preferably be carried out using mechanical methods through lathing, milling or planing. Abrasive waterjet cutting or plasma cutting is also possible. In the latter case, however, the cut edge (seam flank) must be cleanly reworked. Careful grinding without overheating is also permissible.

Striking the arc

The arc should only be struck in the seam area, such as on the weld edges or on an outlet piece, and not on the component surface. Scaling areas are areas in which corrosion more easily occurs.

Included angle

Compared to C-steels, nickel alloys and special stainless steels exhibit lower heat conductivity and greater heat expansion. These properties must be taken into account by larger root openings or root gaps (1 to 3 mm, 0.039 to 0.118 in). Due to the viscosity of the welding material (compared to standard austenites) and the tendency to shrink, opening angles of 60 to 70° – as shown in Figure 1 – have to be provided for butt welds.

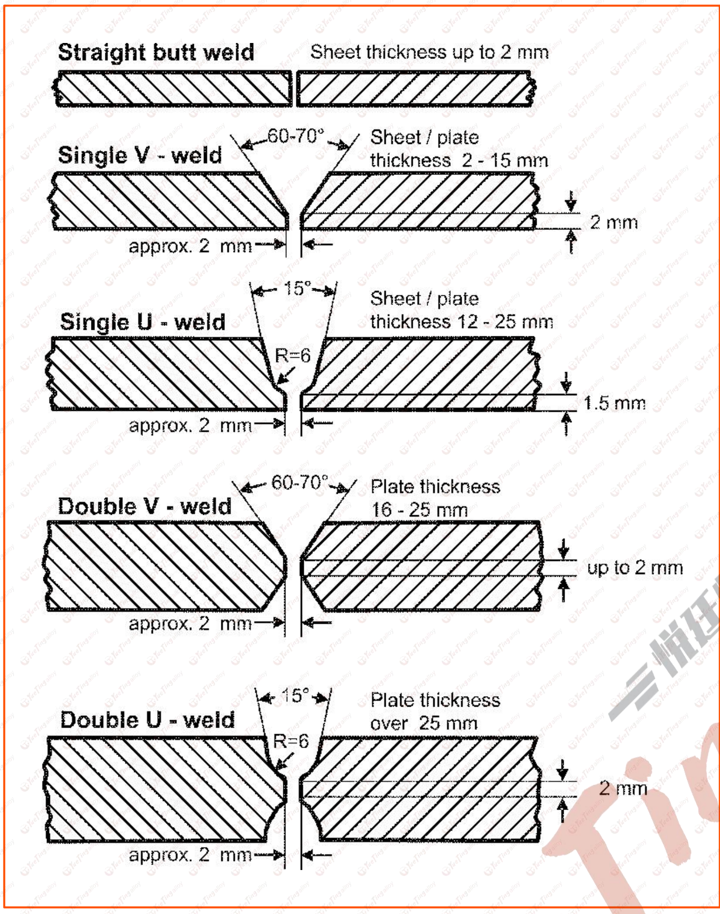

Figure 1 – Seam preparation for welding nickel alloys and special stainless steels

Cleaning

Cleaning of the base material in the seam area (both sides) and the welding filler (e.g. welding rod) should be carried out using acetone.

Welding parameters and influence

It must be ensured in the welding process that work is carried out using targeted heat application, low heat input and rapid heat extraction. The interpass temperature should not exceed 120°C (248 °F). In principle, welding parameters must be checked.

Welding filler

VDM® Alloy 22 can be welded using all conventional processes.

The following welding filler is recommended: VDM® FM 622 (mat. no. 2.4635)
ISO 18274 - S Ni 6022 (NiCr21Mo13Fe4W3) AWS 5.14 - ERNiCrMo10

VDM® FM 59 (mat. no. 2.4607)
ISO 18274 - S Ni 6059 (NiCr23Mo16) AWS 5.14 - ERNiCrMo-13

To achieve optimum corrosion properties, the TIG method is preferable.

Weld strip
VDM® WS 59 (material no. 2.4607) ISO 18274 - B Ni 6059 (NiCr23Mo16) AWS 5.14 - ERNiCrMo-13

Bar electrodes in sleeves
The use of bar electrodes in sleeves is possible.

Post-treatment
If the work is performed optimally, brushing immediately after welding, i.e. while still warm and without additional pickling, will result in the desired surface condition. In other words, heat tints can be removed completely. Pickling, if required or specified, should generally be the last work step in the welding process. The information contained in the section entitled "Descaling and pickling" must be observed. Heat treatments are normally neither required before nor after welding.

Thickness	Welding technique	Filler material		Root pass[1]		Intermediate and final passes		Welding speed	Shielding gas	
Mm (in)		Diameter mm (in)	Speed (m/min)	I in (A)	U in (V)	I in (A)	U in (V)	(cm/min)	Type	Rate (l/min)
3 (0.118)	m-WIG	2.0 (0.079)		90	10	110-120	11	15	I1, R1 with max. 3% H2	8-10
6 (0.236)	m-WIG	2.0-2.4 (0.079-0.0945)		100-110	10	120-140	12	14-16	I1, R1 with max. 3% H2	8-10
8 (0.315)	m-WIG	2.4 (0.045)		100-110	11	130-140	12	14-16	I1, R1 with max. 3% H2	8-10
10 (0.394)	m-WIG	2.4 (0.0945)		100-110	11	130-140	12	14-16	I1, R1 with max. 3% H2	8-10
3 (0.118)	v-WIG[2]	1.0-1.2 (0.039-0.0472)	1.2			150	11	25	I1, R1 with max. 3% H2	12-14
5 (0.197)	v-WIG[2]	1.2 (0.0472)	1.4			180	12	25	I1, R1 with max. 3% H2	12-14
2 (0.0787)	v-WIG HD	1.0 (0.039)				180	11	80	I1, R1 with max. 3% H2	12-14
10 (0.394)	v-WIG HD	1.2 (0.0472)				220	12	40	I1, R1 with max. 3% H2	12-14
4 (0.157)	Plasma[3]	1.2 (0.0472)	1.0	180	25			30	I1, R1 with max. 3% H2	30
6 (0.236)	Plasma[3]	1.2 (0.0472)	1.0	200-220	26			26	I1, R1 with max. 3% H2	30
8 (0.315)	MIG/MAG[4]	1.0 (0.039)	6-7			130-140	23-27	24-30	I1	18
10 (0.394)	MIG/MAG[4]	1.2 (0.0472)	6-7			130-150	23-27	25-30	I1	18

Information

[1] Root pass: it must be ensured that there is sufficient root protection, for example using Ar 4.6, for all inert gas welding processes.

[2] Autom. TIG: the root pass should be welded manually (see manual TIG parameters)

[3] Plasma: recommended plasma gas Ar 4.6 / plasma quantity 3.0-3.5 l/min

[4] GMAW (MIG/MAG): the use of multi-component shielding gases is recommended for MAG welding.

Section energy kJ/cm: autom. TIG-HD max. 6; TIG, GMAW (MIG/MAG) manual, mechanized max. 8; plasma max. 10 The values are intended as guidance to simplify the setting of welding machines.

Table 6 – Welding parameters

Availability

VDM® Alloy 22 is available in the following standard semi-finished forms:

Sheet

Delivery condition: Hot or cold rolled, heat treated, descaled or pickled

Condition	Thickness mm (in)	Width mm (in)	Length mm (in)	Piece weight Kg (lb)
Cold rolled	1-7 (0.039-0.275)	1000-2,500 (39.37-98.42)	≤ 12,500 (492)	
Hot rolled	3-70 (0.118-2.75)	1000-2,500 (39.37-98.42)	≤ 12,500 (492)	≤ 3,600 (7,936.6)

Strip

Delivery condition: Cold rolled, heat treated, pickled or bright annealed

Thickness mm (in)	Width mm (in)	Coil-inside diameter mm (in)			
0,025-0,15 (0.000984-0.00591)	4-230 (0.157-9.06)	300 (11.8)	400 (15.7)	500 (19.7)	–
0,15-0.25 (0.00591-0.00984)	4-720 (0.157-28.3)	300 (11.8)	400 (15.7)	500 (19.7)	–
0,25-0,6 (0.00984-0.0236)	6-750 (0.236-29.5)	–	400 (15.7)	500 (19.7)	600 (23.6)
0,6-1 (0.0236 -0.0394)	8-750 (0.315-29.5)	–	400 (15.7)	500 (19.7)	600 (23.6)
1-2 (0.0394-0.0787)	15-750 (0.591-29.5)	–	400 (15.7)	500 (19.7)	600 (23.6)
2-3 (0.0787-0.118)	25-750 (0.984-29.5)	–	400 (15.7)	500 (19.7)	600 (23.6)

Rolled sheet – separated from the coil – are available in lengths from 250-4,000 mm (9.84 to 157.48 in).

Rod and bar

Delivery condition: Forged, rolled, drawn, heat treated, oxidized, descaled or pickled, turned, peeled, ground or polished

Dimensions	Outside diameter mm (in)	Length mm (in)
General dimensions	6-800 (0.236-31.5)	1,500-12,000 (59.1 – 472)
Material specific dimensions	10-600 (0.393-23.62)	1,500-12.000 (59.1 - 472)

Wire

Delivery condition: Drawn bright, ¼ hard to hard, bright annealed in rings, containers, on spools and headstocks

Drawn mm (in)	Hot rolled mm (in)
0.16-10 (0.006-0.04)	5.5-19 (0.22-0.75)

Other shapes and dimensions such as discs, rings, seamless or longitudinally welded pipes and forgings can be requested.

Publications

The following technical literature has been published about the material VDM® Alloy 22:

U. Heubner et al.: “Nickelwerkstoffe und hochlegierte Sonderedelstähle”, expert Verlag, Renningen, 5th edition, 2012.

U. Heubner, M. Köhler: "Das Zeit - Temperatur - Ausscheidungs- und das Zeit - Temperatur - Sensibilisierungs - Verhalten von hochkorrosionsbeständigen Nickel - Chrom -Molybdän - Legierungen", Werkstoffe und Korrosion 43, 1992, pages 181-190.

Legal notice

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