VDM Metals

A company of ACERINOX

VDM® Alloy 617
Nicrofer 5520 Co

Material Data Sheet No. 4119 **Revision 01**

July 2021

VDM® Alloy 617

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VDM® Alloy 617 is a nickel-chromium-cobalt-molybdenum alloy with excellent mechanical and creep properties up to 1,100 °C (2,000 °F) due to solid solution hardening. As a result of its balanced chemical composition the alloy shows outstanding resistance to high temperature corrosion such as oxidation and carburization.

VDM® Alloy 617 is characterized by:

- very good short-term and long-term mechanical properties up to 1,100 °C (2,000 °F),
- excellent resistance to oxidation up to 1,100 °C (2,000 °F),
- excellent resistance to carburization up to 1,100 °C (2,000 °F),
- good weldability.

Designations and standards

Standard	Material designation
DIN EN	2.4663 - NiCr23Co12Mo
UNS	N06617
ISO	NiCr22Co12Mo9

Product form	DIN	VdTÜV	ASTM	ASME	SAE AMS	ISO
Sheet, plate	17750	485	B-168	SB-168	5888 5889	6208
Strip	17750	[485][1]	B-168	SB-168	5889	6208
Rod, bar	17752	485	B-166	SB-166	5887	
Wire	17753		B-166	SB-166		9724

1) The VdTÜV-Wbl. does not cover strip produced by VDM Metals.

Table 1 – Designations and standards

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Co	Cu	Mo	Ti	Al	P*	S	B*
Min.	44.5	20.0		0.05			10.0		8.0		0.8			
Max.		24.0	3.0	0.15	1.0	1.0	15.0	0.5	10.0	0.6	1.5	0.012	0.015	0.006

Some compositional limits of other specifications may vary slightly

Table 2 – Chemical composition (%) according to to ASTM (*Not specified in ASTM)

Physical properties

Density	Melting range
8.4 g/cm³ 0.303 lb/in.³	1,330 –1,380 °C 2,430 – 2,520 °F

Temperature		Specific heat		Thermal conductivity		Electrical resistivity	Modulus of elasticity		Coefficient of thermal expansion	
°C	°F	J/(Kg · K)	Btu/(lb · °F)	W/(m · K)	Btu · in/(sq. ft · h · °F)	μΩ · cm	GPa	10³ ksi	10^{-6}/K	10^{-6}/°F
20	68	420	0.100	13,4	94	122	212	30.7		
93	200		0.104		101			30.0		6.4
100	212	440		14,7		125	206		11,6	
200	392	465		16,3		126	200		12,6	
204	400		0.111		113			29.0		7.0
300	572	485		17,7		127	194		13,1	
316	600		0.117		125			28.0		7.4
400	752	515		19,3		128	188		13,6	
427	800		0.124		137			26.9		7.6
500	932	545		20,9		129	181		13,9	
538	1,000		0.131		149			25.8		7.7
600	1,112	565		22,5		131	173		14,0	
649	1,200		0.137		161			24.6		8.0
700	1,292	595		23,9		133	166		14,8	
760	1,400		0.144		173			23.3		8.4
800	1,472	615		25,5		134	157		15,4	
871	1,600		0.150		185			21.9		8.7
900	1,652	645		27,1		135	149		15,8	
982	1,800		0.157		197			20.4		9.0
1,000	1,832	665		28,7		138	139		16,3	

Table 3 – Typical physical properties at room and elevated temperatures

Metallurgical structure

VDM® Alloy 617 has a face-centered cubic structure with good metallurgical stability. Its excellent high-temperature strength is achieved by solid-solution hardening. The alloy is not age-hardenable.

Mechanical properties

The following mechanical properties apply to VDM® Alloy 617 in the solution-annealed and quenched condition and in the stated semi-finished forms and dimensions. Specified properties of material outside these size ranges are subject to special enquiry.

Product	Dimensions		Testing direction	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	%
Sheet and strip	Cold rolled < 6	< 0.25	transverse	350	51	750	55	750	109	35
Plate	Hot rolled ≤ 80	< 3		300	44	700	48	700	102	
Rod and bar	≤ 300	≤ 12	transverse	300	44	680	48	680	94	30
			longitudinal							35

Table 4 – Mechanical properties at room temperature; minimum values according to VdTÜV Data Sheet 485

Hardness: surface hardness of solution-treated and machined forgings: approx. 200 HB30

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	300	43.5	330	47.9	700	101.5	35
38	100	(290)	(42.1)	(315)	(45.7)	(680)	(98.6)	
100	212	270	39.1	300	43.5	650	94.3	
149	300	(250)	(36.3)	(285)	(41.3)	(640)	(92.8)	
200	392	230	33.4	260	37.7	620	89.9	
204	400	(230)	(33.4)	(260)	(37.7)	(620)	(89.9)	
300	572	220	31.9	250	36.3	600	87.0	
316	600	(218)	(31.6)	(245)	(35.5)	(595)	(86.3)	
400	752	210	30.5	240	34.8	570	82.7	
427	800	(208)	(30.2)	(235)	(34.1)	(560)	(81.2)	
500	932	200	29.0	225	32.6	540	78.3	
538	1,000	(198)	(28.7)	(220)	(31.9)	(530)	(76.9)	
600	1,112	190	17.6	210	30.5	510	74.0	
649	1,200	(188)	(27.3)	(208)	(30.2)	(480)	(69.6)	
700	1,292	185	26.8	205	29.7	400	58.0	
750	1,382	180	26.1	200	29.0	340	49.3	
760	1,400	(178)	(25.8)	(198)	(28.7)	(330)	(47.9)	

(xxx) = approximate values interpolated from graphs

Table 5 – Mechanical properties at elevated temperatures; minimum values according to VdTÜV Data Sheet 485

Temperature		Stress to produce 1% creep				Creep-rupture strength			
		$R_{p\ 1,0/10^4\ h}$		$R_{p\ 1,0/10^5\ h}$		$R_{m/10^4\ h}$		$R_{m/10^5\ h}$	
°C	°F	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi
600	1112					260	37.7	190	27.6
650	1202	148	21.5	97	14.1	170	24.7	125	18.1
700	1292	99	14.1	66	9.6	123	17.8	95	13.8
750	1382	68	9.9	44	6.4	90	13.1	65	9.4
800	1472	45	6.5	28	4.1	65	9.4	43	6.2
850	1562	29	4.2	18	2.6	45	6.5	27	3.9
900	1652	19	2.8	10	1.45	30	4.4	16	2.3
950	1742	11	1.6	4	0.58	18	2.6	8.5	1.2
1000	1832	5.5	0.8	1.0	0.15	10	1.45	(4.5)	(0.65)

Table 6 – Typical stresses to produce 1% creep in solution-treated VDM® Alloy 617 and creep-rupture strength

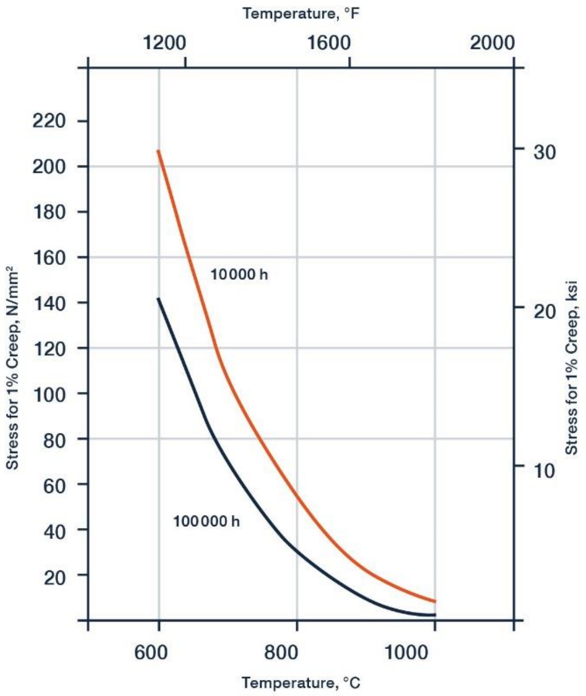

Figure 1 – Typical stresses for 1 % creep of solution-treated VDM® Alloy 617

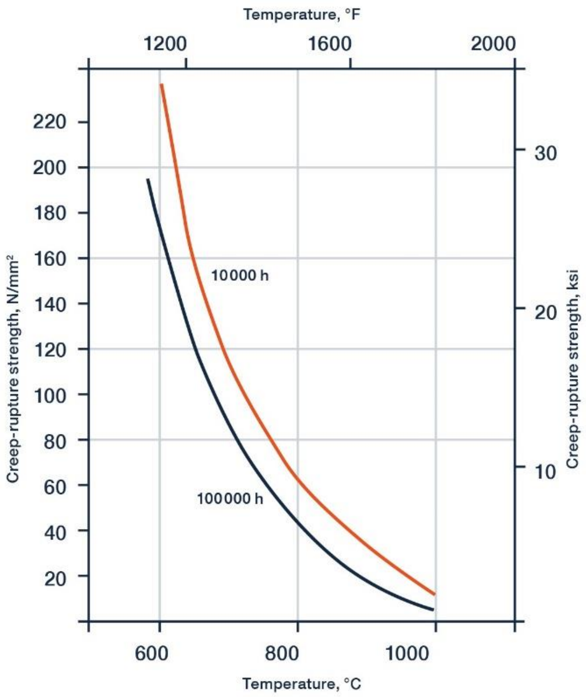

Figure 2 – Typical creep-rupture strength of solution-treated VDM® Alloy 617

ISO V-notch impact toughness

Average values at RT:

transverse ≥ 100 J/cm²
longitudinal ≥ 150 J/cm²

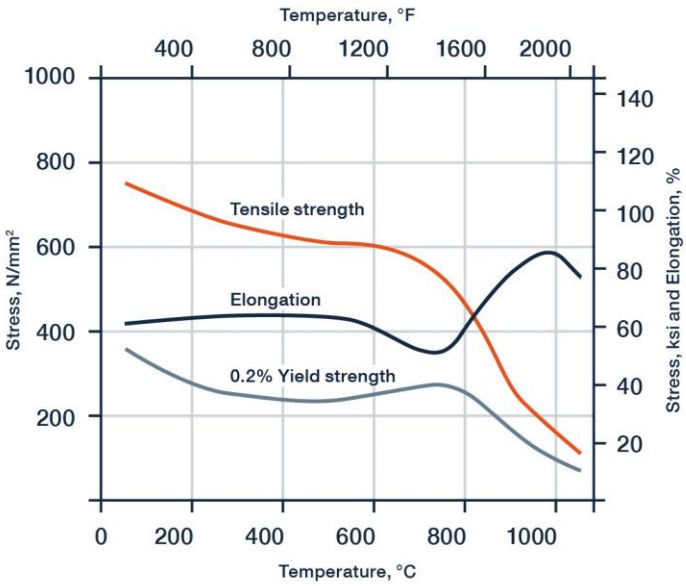

Figure 3 – Typical short-time properties of solution-treated VDM® Alloy 617 sheet and plate at elevated temperature

Relaxation cracking susceptibility

VDM® Alloy 617 is susceptible to relaxation cracking if new solution-annealed and welded semi-fabricated products are exposed to service temperatures within the temperature range of 550 to 780 °C (1,020 to 1,436 °F) without a prior postweld stabilizing heat treatment (PWHT) at 980 °C (1,800 °F) for 3 hrs. The heating and cooling rates for such stabilizing heat treatments are not critical.

The subsequent service temperature range within which relaxation cracking may occur extends further to 500 to 780 °C (932 to 1,436 °F), if products are reused which have already been in service and which have been repair-welded with matching alloy 617 consumables without a following stabilizing heat treatment at 980 °C (1,800 °F) for 3 hrs.

Corrosion resistance

VDM® Alloy 617 exhibits excellent resistance to hot corrosion such as oxidation and carburization under static and cyclic conditions up to temperatures of about 1,100 °C (2,000 °F). These properties, combined with outstanding mechanical properties, make this alloy especially suitable for high temperature applications.

Additionally the high contents of nickel, chromium and molybdenum contribute to the good overall corrosion resistance of VDM® Alloy 617 in a variety of aggressive media.

Applications

VDM® Alloy 617 is especially suitable where high temperatures and particularly high mechanical stresses are present. The alloy is recommended for service temperatures up to 1,000 °C (1,830 °F). Where weight savings are mandatory, VDM® Alloy 617 is particularly effective as fabrication of thin-walled parts is possible.

Typical fields of application for VDM® Alloy 617 are:

- components for industrial and aircraft gas turbines, such as combustion cans, housings, turbine rings, and other parts exposed to high temperatures,
- air heaters,
- furnace muffles and radiant heater tubes,
- high-temperature heat exchangers, valves and springs,
- high-temperature gas-cooled nuclear reactors, such as the helium/helium intermediate heat exchanger for the high-temperature section of the nuclear process-heat prototype plant (PNP),
- equipment for the chemical process industry (CPI), e. g. for the productions of styrene,
- pigtails and furnace tubing in the petrochemical industry.

Fabrication and heat treatment

VDM® Alloy 617 can readily be hot and cold worked, fabricated and machined. Hot and cold working, however, require high-power machines owing to the strength of the material.

Heating
Workpieces must be clean and free from all kinds of contaminants before and during any heat treatment. VDM® Alloy 617 may become embrittled if heated in the presence of contaminants such as sulfur, phosphorus, lead and other low-melting-point metals. Sources of such contaminants include marking and temperature-indicating paints and crayons, lubricating grease and fluids, and fuels. Fuels must be as low in sulfur as possible. Natural gas should contain less than 0.1 wt.-% sulfur. Fuel oils with a sulfur content not exceeding 0.5 wt.-% are suitable. Due to their close control of temperature and freedom from contamination, thermal treatments in electric furnaces under vacuum or an inert gas atmosphere are to be preferred.

Treatments in air atmosphere and alternatively in gas-fired furnaces are acceptable though, if contaminants are at low levels so that a neutral or slightly oxidizing furnace atmosphere is attained. A furnace atmosphere fluctuating between oxidizing and reducing must be avoided as well as direct flame impingement on the metal.

Hot forming
Due to the very high hot strength, considerable forces are required during hot forming. VDM® Alloy 617 may be hot worked in the temperature range 1200 to 950 °C (2190 to 1740 °F), followed by water quenching or rapid air cooling. Heat treatment after hot working is recommended to obtain optimum properties. For heating up workpieces should be charged into the furnace at maximum working temperature (solution-anneal temperature).

Cold forming
Cold working should be carried out on annealed material. VDM® Alloy 617 has a higher work-hardening rate than austenitic stainless steels.This should be taken into account when selecting forming equipment. Interstage annealing may be necessary with high degrees of cold forming. After cold reduction of more than 10 %, or more than 5 % for applications at temperatures above 900 °C (1650 °F) solution annealing is required before use.

Heat treatment
Solution heat treatment should be carried out in the temperature range 1,150 to 1,200 °C (2,100 to 2,190 °F). Water quenching is essential for maximum creep resistance. Below 1.5 mm (0.06 in.) thickness, rapid air cooling may be applied. Stress-relief annealing may be performed at temperatures up to 870 °C (1,600 °F). For any thermal treatment the material should be charged into the furnace at maximum annealing temperature observing the precautions concerning cleanliness mentioned earlier under **'Heating'.**

Descaling and pickling
High-temperature alloys develop a protective oxide layer in service. Pre-oxidation in air can produce increased corrosion resistance. Therefore on the basis of the end use the necessity of descaling should be checked. Oxides of VDM® Alloy 617 and discoloration adjacent to welds are more adherent than on stainless steels. Grinding with very fine abrasive belts or discs is recommended. Care should be taken to prevent tarnishing. Before pickling in a nitric/hydrofluoric acid mixture, the surface oxide layer must be broken up by abrasive blasting or grinding or by pre-treatment in a fused salt bath. Particular attention should be paid to the pickling time and temperature.

Machining
VDM® Alloy 617 should preferably be machined in the solutiontreated condition. The alloy's high work-hardening rate should be considered, i.e., only low surface cutting speeds with not too high a rate of feed should be selected. Tools should be engaged at all times. An adequate depth of cut is important in order to cut below the previously formed work-hardened zone.

Welding information

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

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 4 – have to be provided for butt welds.

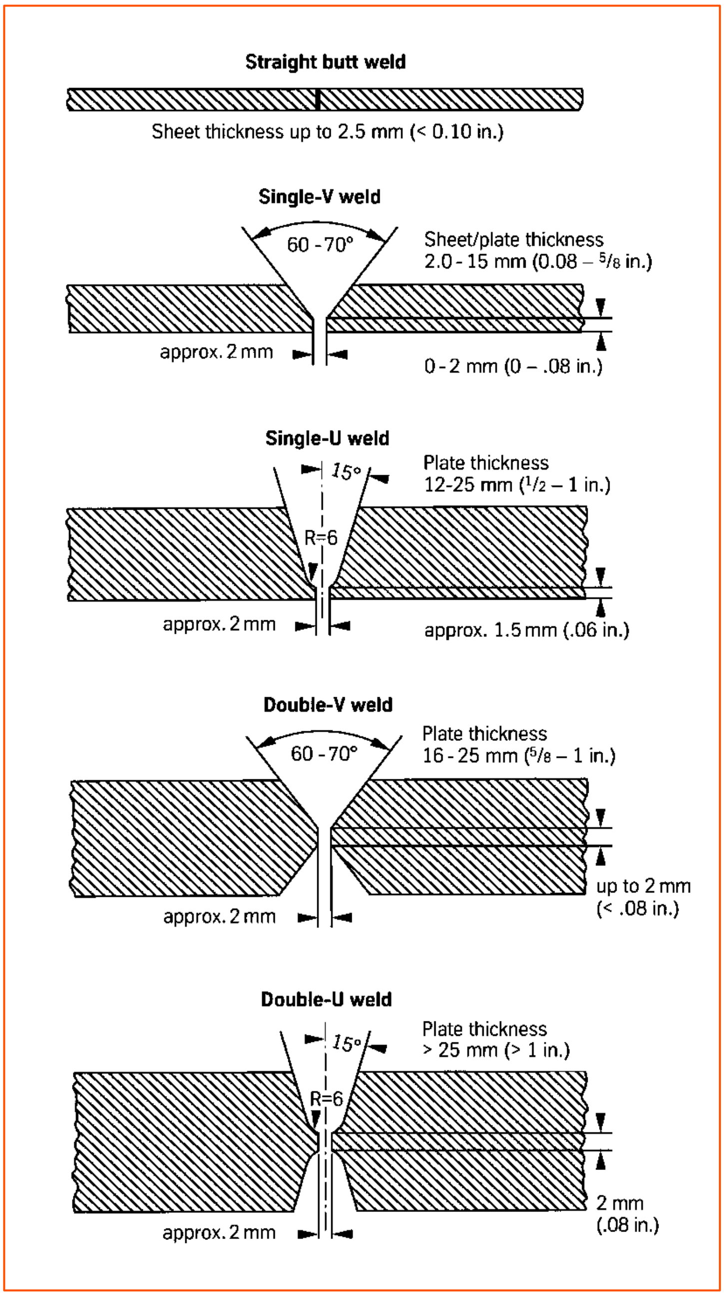

Figure 4 – Seam preparation for welding nickel alloys and special stainless steels

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 technique

VDM® Alloy 617 can be joined to itself and to many other metals by conventional welding processes. These include GTAW (TIG), GMAW (MIG/MAG), plasma arc, electron beam welding and SMAW (MMA). Pulsed arc welding is the preferred technique.

For welding, VDM® Alloy 617 should be in the annealed condition and be free from scale, grease and markings. When welding the root, care should be taken to achieve best-quality root backing (argon 99.99), so that the weld is free from oxides after welding the root. Any heat tint should be removed preferably by brushing with a stainless steel wire brush while the weld metal is still hot.

Welding filler

For the gas-shielded welding processes, filler metal with the same composition as the base metal is recommended:

Bare electrodes:

VDM® FM 617 (W-Nr. 2.4627)
UNS N06617
AWS A5.14: ERNiCrCoMo-1
DIN EN ISO 18274: S Ni 6617 (NiCr22Co12Mo

Covered electrodes:

W.-Nr. 2.4628
UNS W86117
AWS A5.11: ENiCrCoMo-1
DIN EN ISO 14172: E Ni 6617 (NiCr22Co12Mo)

Welding parameters and influences

It must be ensured that work is carried out using targeted heat application and low heat input as listed in Table 6 as an example. The stringer bead technique is recommended. The interpass temperature should not exceed 120 °C (248 °F). In principle, checking of welding parameters is necessary.

Heat input Q can be calculated as follows:

$$Q=\frac{U \cdot I \cdot 60}{v \cdot 1{,}000}\ \left(\frac{kJ}{cm}\right)$$

U = arc voltage, volts
I = welding current strength, amperes
v = welding speed, cm/min

Post-treatment

Brushing with a stainless steel wire brush immediately after welding, i.e., while the metal is still hot, generally results in removal of heat tint and produces the desired surface condition without additional pickling. Pickling, if required or prescribed, however, would generally be the last operation performed on the weldment. Also refer to the information on **'Descaling and pickling'**. Neither pre- nor postweld thermal treatments are normally required.

However, to eliminate the risk of relaxation cracking of new solution-annealed and welded semi-fabricated products subsequently in use as stress-bearing components at service temperatures of 550 to 780 °C (1,020 to 1,436 °F) the stabilization annealing recommendations given under **'Relaxation cracking susceptibility'** should be adhered to.

Such a stabilizing heat treatment should also be carried out on products which had already been in service and which have been repair-welded with matching VDM® Alloy 617 consumables before they are returned into service at the extended temperature range of 500 to 780 °C (932 to 1,436 °F).

Thickness	Welding technique	Filler material		Root pass[1]		Intermediate and final passes		Welding speed	Shielding gas	
(mm)		Diameter (mm)	Speed (m/min)	I in (A)	U in (V)	I in (A)	U in (V)	(cm/min)	Type	Rate (l/min)
3.0	Manual GTAW	2.0		90	10	110 – 120	11	approx. 15	Ar W3[1]	8 – 10
6.0	Manual GTAW	2.0-2.4		100 – 110	10	120 – 140	12	14-16	Ar W3[1]	8 – 10
8.0	Manual GTAW	2.4		100 – 110	11	130 – 140	12	14-16	Ar W3[1]	8 – 10
10.0	Manual GTAW	2.4		100 – 110	11	130 – 140	12	14-16	Ar W3[1]	8 – 10
3.0	Automat. GTAW	1.2	Approx. 1.2	Manual GTAW		150	11	25	Ar W3[1]	12 – 14
5.0	Automat. GTAW	1.2	Approx. 1.4	Manual GTAW		150	12	25	Ar W3[1]	12 – 14
2.0	Hot wire GTAW	1.0				180	11	80	Ar W3[1]	12 – 14
10.0	Hot wire GTAW	1.2		Manual GTAW	220	220	12	40	Ar W3[1]	12 – 14
4.0	Plasma arc	1.2	approx. 1.0	approx. 180	25			30	Ar W3[1] Ar 4.6[2]	30 3.0
6.0	Plasma arc	1.2	approx. 1.0	200 – 220	26			26	Ar W3[1] Ar 4.6[2]	30 3.5
8.0	GMAW (MIG/MAG[3])	1.0	6-7	Manual GTAW		130 – 140	23 – 27	24 – 30	Ar 4.6[3]	18
10.0	GMAW (MIG/MAG[3])	1.2	6-7	Manual GTAW		130 – 150	23 – 27	25 – 30	Ar 4.6[3]	18
6.0	SMAW (MMA)	2.5		40 – 70	approx. 21	40 – 70	approx. 21			
8,0	SMAW (MMA)	2.5 – 3.25		40 – 70	approx. 21	70 – 100	approx. 22			
16.0	SMAW (MMA)	4.0				90 – 130	approx. 22			

1) Argon or argon + max. 3 % hydrogen
2) Plasma gas
3) For MAG welding the use of the multi-component shielding gas Cronigon He30S, for example, is recommended.
In all gas-shielded welding operations, ensure adequate back shielding. Figures are for guidance only and are intended to facilitate setting of the welding machines.

Table 7 – Welding parameters

Welding process	Heat input per unit length kJ/cm
GTAW, manual, fully mechanised	Max. 8
Hot wire GTAW	Max. 6
Plasma arc	Max.10
GMAW, MIG/MAG, manual, fully mechanised	Max. 8
SMAW, manual metal arc (MMA)	Max. 7

Table 8 – Heat input per unit length (guide values).

Availability

VDM® Alloy 617 is available in the following standard semi-finished forms:

Plate, sheet

Delivery condition: Hot or cold rolled, annealed, de-scaled resp. pickled

Condition	Thickness mm (in)	Width mm (in)	Length mm (in)	Piece weight kg
Cold rolled	1 – 7 (0.04 – 0.28)	1,000 – 2,500 (39.4 – 98.43)	≤ 12,500 (492.13)	
Hot rolled	3 – 100 (0.12 – 3.94)[1)]	1,000 – 2,500 (39.4 – 98.43)	≤ 12,500 (492.13)	≤ 2,700 (106.3)[2)]

[1)] 2 mm thickness on request
[2)] Piece weights up to 4,500 kg on request

Strip

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

Thickness mm (in)	Width mm (in)	Coil – inside diameter mm			
0.02 – 0.15 (0.0008 – 0.006)	4 – 230 (0.16 – 9.06)	300	400	500	–
0.15 – 0.25 (0.006 – 0.01)	4 – 720 (0.16 – 28.34)	300	400	500	–
0.25 – 0.6 (0.01 – 0.024)	6 – 750 (0.24 – 29.5)	–	400	500	600
0.6 – 1 (0.024 – 0.04)	8 – 750 (0.32 – 29.5)	–	400	500	600
1 – 2 (0.04 – 0.08)	15 – 750 (0.6 – 29.5)	–	400	500	600
2 – 3 (0.08 – 0.12)	25 – 750 (0.98 – 29.5)	–	400	500	600

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

Rod

Delivery condition: Forged, rolled, drawn, heat-treated, oxidized, de-scaled or pickled, machined, peeled, ground or polished

Condition	Outside diameter mm (in)	Length mm (in)
Rolled, drawn	6 – 125 (0.24 – 31.5)	≤ 12,000 (472.44)
Forged	125 – 600 (0.47 – 23.62)	≤ 7,500 (295.28)

Wire

Delivery condition: bright drawn, 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 – 0.4)	5.5 – 19 (0.22 – 0.75)

Publications

The following technical literature has been published about the material VDM® Alloy 617:

U.Brill: Korrosion von Nickel, Cobalt und Nickel- und CobaltBasislegierungen; Reprint of Korrosion und Korrosionsschutz, 1992.

U.Brill, M. Rockel: High-temperature alloys from Krupp VDM for industrial engineering; VDM-Report No. 25, 2000.

U. Heubner, J.Klöwer et al.: Nickel alloys and high-alloy special stainless steels; expert Verlag, 3rd revised edition, 2003. ISBN 3-8169-2195-7

Legal notice

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