VDM Metals

VDM® Alloy 718
Nicrofer 5219 Nb

Material Data Sheet No. 4127
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VDM® Alloy 718

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VDM® Alloy 718 is an age hardenable nickel-chrome-iron-molybdenum alloy. The age hardening is achieved by specific additions of niobium, titanium and aluminum. It can be delivered in solution-annealed or hardened condition. VDM® Alloy 718 is characterized by:

- Good processing properties in the solution-annealed condition
- Good mechanical short and long-term properties, and great fatigue strength in the age hardened condition
- Good creep resistance up to 700 °C (1,300 °F)
- Good oxidation resistance up to approx. 1,000°C (1,830 °F)
- Excellent mechanical properties in low temperatures

Designations and standards

Standard	Material designation
EN	2.4668 - NiCr19Fe19Nb5Mo3
ISO	NiCr19Nb5Mo3
UNS	N07718
AFNOR	NC19FeNb
NA	51

Table 1a – Designations and standards

Designations and standards

Product form	DIN	DIN EN	ISO	ASTM	ASME	SAE AMS
Sheet, plate	17744 17750			B 670		5596 5663
Strip	17744 17750	10302 2407	6208	B 670		5596 5597
Rod, bar, forging	17744 17752			B 637	SB 637	5662 5663 5664
Wire	17744					

Table 1b – Designations and standards

Chemical composition

	Ni	Cr	Fe	C	Mn	Si	Cu	Mo	Co	Nb	Ta	Al	Ti	B	P	S	Pb	SE	Bi
Min.	50	17	Rest					2.8		4.75		0.2	0.65						
Max.	55	21		0.08	0.35	0.35	0.3	3.3	1	5.5	0.05	0.8	1.15	0.006	0.015	0.015	5 ppm	3 ppm	0.3 ppm

Table 2 – Chemical composition (%) according to ASTM and SAE AMS

Depending on the intended application conditions, narrower analysis limits apply to certain alloy elements. This is true in particular for carbon and niobium, but to lesser extent also for aluminum and titanium. The purpose of this limitation is to optimize the structure and mechanical properties with regard to the intended use. Accordingly, for example, alloys with carbon and niobium concentrations near the upper limit according to ASTM are best suited for high-temperature applications, while lesser carbon and niobium concentrations result in material structures that conform better to the requirements of corrosive conditions.

Physical properties

Density	Melting range	Relative magnetic permeability at 20 °C (68 °F)	Curie temperature
8.26 g/cm³ (0.04 lb/in³) at 20 °C (68 °F)	1,257-1,342 °C (2,295-2,448 °F)	1.001 (Maximum)	Solution-annealed: -195 °C (-319 °F) Solution-annealed and age hardened: -112 °C (-170 °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	460	0.110	11.5	79.8	118	204	29.6	14.1	7.73
100	212	458	0.109	12.1	84.0	120	199	28.9	14.1	7.73
200	392	468	0.112	13.5	93.7	123	193	28.0	14.1	7.73
300	572	485	0.116	15.2	105.5	125	187	27.1	14.2	7.89
400	762	501	0.120	17.1	118.7	127	180	26.1	14.4	8.00
500	932	514	0.123	18.8	130.4	128	173	25.1	14.8	8.22
600	1,112	533	0.127	20.6	142.9	130	166	24.1	15.3	8.50
700	1,292	604	0.144	24.1	167.2	131	158	22.9	16.4	9.11
800	1,472	615	0.147	24.2	167.9	132	150	21.8	17	9.44
900	1,652	626	0.150	25	173.5	133	143	20.7	17.4	9.67
1,000	1,832	637	0.152	25.8	179.0	134	134	19.4		
1,100	2,012	635	0.152	26.6	184.6	118	126	18.2		
1,200	2,192	658	0.157	28.7	199.1	120	122	17.7		

Table 3 – Typical physical properties of VDM® Alloy 718 at room and elevated temperatures

Microstructural properties

VDM® Alloy 718 has an austenitic structure; multiple phases can be precipitated. By means of different heat treatments, graduated mechanical properties of the material can be reached. The excellent mechanical properties of VDM® Alloy 718 result from the γ''-formation during the precipitation hardening. More information can be found in the section on "heat treatment".

Mechanical properties

The following mechanical properties of VDM® Alloy 718 apply to hot or cold-formed material in the solution-annealed or solution-annealed and age hardened condition in the specified dimensions. Material with specified properties outside of the listed ranges must be requested separately.

Temperature		**Yield strength $R_{p\,0.2}$**		**Tensile strength R_m**		**Elongation A**	**Reduction of area Z**
°C	**°F**	**MPa**	**ksi**	**MPa**	**ksi**	**%**	**%**
20	68	1,030	149.4	1,280	185.6	12	15
100	212	1,060	153.7	1,280	185.6	12	15
200	392	1,040	150.8	1,250	177.7	12	15
300	572	1,020	147.9	1,220	176.9	12	15
400	762	1,000	145.0	1,180	171.1	12	15
500	932	980	142.1	1,150	166.8	12	15
600	1,112	950	137.8	1,060	153.7	12	15
650	1,202	860	124.7	1,000	145.0	12	15
700	1,292	870	126.2	1,040	150.8	12	15
750	1,382	760	110.2	880	127.6	12	15
800	1,472	640	92.8	780	113.1	12	15

Table 4 – Typical short-term properties of solution-annealed and age hardened VDM® Alloy 718 at elevated temperatures

Product form	Dimensions		Yield strength $R_{p\,0.2}$		Tensile strength R_m		Elongation A	Reduction of area Z
	mm	in	MPa	ksi	MPa	ksi	%	%
Sheet, plate	0.25-25.4	0.01-1	≥ 1,034	≥ 150.0	≥ 1,241	≥ 180.0	≥ 12	
Strip	< 0.25	< 0.01	≥ 1,034	≥ 150.0	≥ 1,241	≥ 180.0		
Rod, bar	≤ 127	≤ 5	≥ 1,030	≥ 149.4	≥ 1,240	≥ 179.8	≥ 6	≥ 8

Table 5 – Mechanical properties at room temperature according to SAE AMS 5596 (sheet, plate and strip) and SAE AMS 5662 or 5663 (rod, bar) of solution-annealed and age hardened VDM® Alloy 718

Temperature		Creep limit $R_{p\,1.0}/10^4$ h		$R_{p\,1.0}/10^5$ h		Creep strength $R_m/10^4$ h		$R_m/10^5$ h	
°C	°F	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi
550	1,022	783	113.6	643	93.3	810	117.5	673	97.6
600	1,112	580	84.1	430	62.4	620	89.9	505	73.2
650	1,202	370	53.7	240	34.8	425	61.6	290	42.1
700	1,292	200	29	88	12.8	248	36	132	19.1
750	1,382	70	10.2	23	3.3	125	18.1	44	6.4
800	1,472	19	2.8	6.1	0.9	36	5.2	12	1.7

Table 6 – Creep limits according to DIN EN 10302 of solution-annealed and age hardened VDM® Alloy 718

Brinell hardness

< 277, rod, bar, solution-annealed condition according to SAE AMS 5662 or 5663
> 331, rod, bar, solution-annealed and age hardened condition according to SAE AMS 5662 or 5663

Corrosion resistance

Based on the high chrome and molybdenum concentrations, VDM® Alloy 718 has a good resistance in many media against abrasive and local corrosion such as pitting. By virtue of its high nickel content, VDM® Alloy 718 also has good resistance against stress corrosion cracking.

Applications

Based on its high-temperature resistance up to 700 °C (1,300 °F), its excellent oxidation and corrosion resistance, and its good workability, VDM® Alloy 718 is used in many demanding applications. Originally, it was developed and used for static and rotating components in aircraft turbines such as housings, mounting elements and turbine disks, where tough requirements apply for creep resistance and fatigue behavior, in particular for the rotating applications.

Due to its properties, its good workability and efficiency, the material is additionally widely used for static and rotating components in stationary gas turbines, rocket drives and spacecraft, motor vehicle turbo chargers, high-strength screws, springs and mounting elements, and for heat-resistant tools in forgeries, extruders and separating shearers.

The variant VDM® Alloy 718 CTP, which is laid out specifically for the requirements of the oil and gas industry, finds increasing uses in drilling equipment and pump shafts. The components used must ensure an efficient and safe oil and gas extraction with increasing drilling hole depth and pressures and temperatures becoming more critical, and withstand the acid gas environment (H_2S, CO_2, chloride) that is prevalent there (see special data sheet VDM® Alloy 718 CTP).

Fabrication and heat treatment

VDM® Alloy 718 can readily be hot- and cold-worked and machined.

Heating
Workpieces must be clean and free of any contaminants before and during heat treatment. Sulfur, phosphor, lead and other low-melting-point metals can lead to damages when heat treating VDM® Alloy 718. Sources of such contaminants include marking and temperature-indicating paints and crayons, lubricating grease and fluids, and fuels. Heat treatments can be carried out in gas fired, oil fired or electric furnaces in air, under vacuum or inert gas atmosphere. Fuels should contain as little sulfur as possible. Natural gas should contain less than 0.1 wt.-% of sulfur. Heating oil with a sulfur content of maximum 0.5 wt.-% is also suitable with a slightly oxidizing atmosphere. The workpieces may not be contacted directly by flames.

Hot working
The hot working should generally be conducted after the homogenization with subsequent cooling in air. It should be done evenly in order to receive a homogeneous structure and to prevent the formation of a duplex grain structure.

Cold working
Cold working should take place in the solution-annealed condition. The material has a higher work hardening rate than austenitic stainless steels. This must be taken into account during design and selection of forming tools and equipment and during the planning of the forming processes.

Heat treatment
Through various heat treatments, the mechanical properties of VDM® Alloy 718 can be adjusted specifically. In the solution-annealed condition, the material can be processed and worked more easily. In the solution-annealed and age hardened condition, VDM® Alloy 718 has a high mechanical strength. The solution-annealed condition is obtained through a heat treatment in the temperature range from 940 to 1,065 °C (1,724 to 1,949 °F). Here, for example, annealing by inserting into a pre-heated furnace at a temperature of 980 °C (1,796 °F) for 1 hour is common. Cooling can be done by placing the workpiece in water or oil or also in open air. The hardening takes place by annealing in the temperature range from 620 to 790 °C (1,148 to 1,454 °F). A two-stage heat treatment is common here with insertion in a pre-heated furnace at 720 °C (1,328 °F) for 8 hours, followed by a furnace cool-down to 620 °C (1,148 °F) and repeated holding for 8 hours. Cooling is usually done in open air.

Descaling and pickling
Oxides from VDM® Alloy 718 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 which may be performed in a nitric/hydrofluoric acid mixture with proper control of pickling time and temperature, the surface oxide layer must be broken up by abrasive blasting or by carefully performed grinding.

Machining
While VDM® Alloy 718 in the solution-annealed condition is easier to process and the strain on tools is less, better surface quality is achieved in the hardened condition. The best results in terms of the surface quality of the finished product are achieved by pre-treatment before hardening and by finishing in the hardened condition. As the alloy is more prone to work-hardening than other low alloyed materials, low cutting speeds and appropriate feed rates should be used and the tool should stay engaged at all times. Sufficient chip depths are important to get below the work-hardened surface layer.

Welding

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 carbon steels are being processed, must be provided. Considerable cleanliness is required, and draughts should be avoided during inert gas 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.

Welding edge preparation
Welding edge 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.

Scaling
Scaling may only be carried out in the seam area, e.g. along the seam flanks or outlets, and should not be carried out on the workpiece surface. Scaling areas are areas in which corrosion more easily occurs.

Included angle
Compared to carbon steels, nickel alloys and special stainless steels have a lower heat conductivity and greater heat expansion. These properties must be taken into account by a larger root openings or root gaps (1 to 3 mm; 0.04-1.2 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 – must be provided for butt welds.

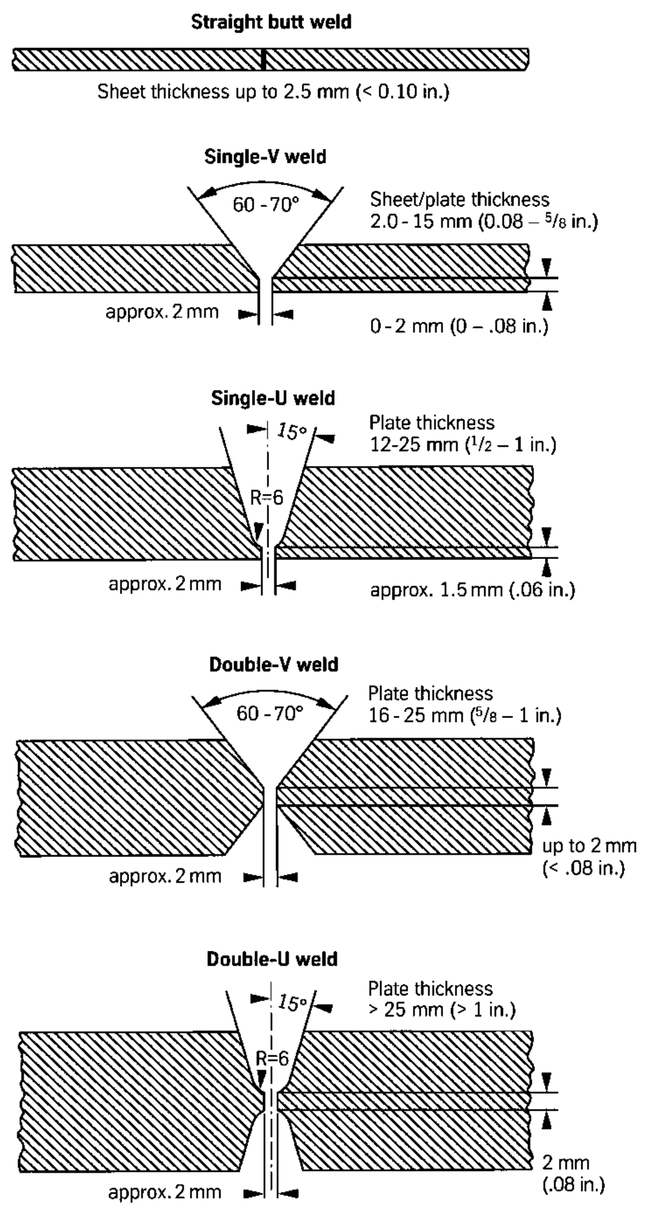

Figure 1 – Seam preparation for welding nickel alloys and special stainless steels.

Cleaning

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

Welding process

VDM® Alloy 718 can be welded in a number of different welding processes. Wherever the inert gas welding process is used, impulse technology is preferable. The material should be in the solution-annealed condition for welding, and should be free of scale, grease and markings. When welding the root, care should be taken to achieve best quality root backing (e.g. argon 4.6), so that the weld is free from oxides after welding the root. Any temper colors must be removed, preferably using a stainless steel brush, while the welding seam is still hot.

Filler material
The following filler materials are recommended:

TIG/MIG

VDM® FM 718 (W. no. 2.4667)
DIN EN ISO 18274: S Ni 7718 (SG-NiCr19NbMoTi)
AWS A 5.14: ERNiFeCr-2

The use of bar electrodes in sleeves is possible.

Welding parameters and influences
It must be ensured that work is carried out using targeted heat application and low heat input. The interpass temperature should not exceed 100 °C (212 °F). The stringer bead technique is recommended. In this context, also the right choice of wire and bar electrode diameters should be pointed out. Corresponding energy inputs per unit length result from the aforementioned notes, which are shown as examples in Table 7. 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, Volt
I = welding current voltage, Ampere
v = welding speed, cm/minute

Post-weld treatment
During optimum implementation of the work brushing directly after welding, in other words, in a hot condition, without additional pickling results in the required surface condition, i.e. temper color can be removed completely. Once the welding work is finished, hardening can be conducted to achieve a maximum of firmness. On this topic, see the section “Heat treatment": Pickling, if required or specified, should generally be the last operation in the welding process. Information contained in the section entitled "Descaling and pickling" must be observed.

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	manual TIG	2	–	90	10	110-120	11	15	I1, R1 with max. 3% H2	8-10
6	manual TIG	2-2,4	–	100-110	10	120-140	12	14-16	I1, R1 with max. 3% H2	8-10
8	manual TIG	2,4	–	100-110	11	130-140	12	14-16	I1, R1 with max. 3% H2	8-10
10	manual TIG	2,4	-	100-110	11	130-140	12	14-16	I1, R1 with max. 3% H2	8-10
3	autom. TIG[2]	1,2	1,2	-	-	150	11	25	I1, R1 with max. 3% H2	12-14
5	autom. TIG[2)]	1,2	1,4	-	-	180	12	25	I1, R1 with max. 3% H2	12-14
2	autom. TIG HD[2]	1	-	-	-	180	11	80	I1, R1 with max. 3% H2	12-14
10	autom. TIG HD[2]	1,2	-	-	–	220	12	40	I1, R1 with max. 3% H2	12-14
4	Plasma[3]	1,2	1	180	25	-	–	30	I1, R1 with max. 3% H2	30
6	Plasma[3]	1,2	1	200-220	25	-	–	26	I1, R1 with max. 3% H2	30

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

[2] The root pass should be welded manually (see manual TIG).

[3] Recommended plasma gas Ar 4.6 / rate 3.0 to 3.5 l/min

Section energy kJ/cm:
autom. TIG HD max. 6, TIG, GMAW manual, autom. max. 8; Plasma max. 10

Figures are for guidance only and are intended to facilitate setting of the welding machines.

Table 7 - Welding parameters

Availability

VDM® Alloy 718 is available in the following standard semi-finished product forms:

Sheet and plate

Delivery condition: hot or cold-rolled, heat-treated, de-scaled or pickled

Condition	Thickness mm (in)	Width mm (in)	Length mm (in)	Piece weight kg
Cold rolled	1.1-7 (0.04-0.28)	≤ 2,000 (78.74)	≤ 5,500 (216.54)	≤ 1,100
Hot rolled*	3-8 (0.12-0.31) 8-50 (0.31-1.97)	≤ 2,500 (95.43) ≤ 2,500 (95.43)	≤ 5,500 (216.54) ≤ 8,000 (314.96)	≤ 1,100 ≤ 1,100

* 2 mm (0.08 in) thickness on request

Strip

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

Thickness mm (in)	Width mm (in)	Coil - inside diameter mm			
0,025-0,15 (0.001-0.0059)	4-230 (0.16-9.06)	300	400	500	–
0.15-0.25 (0.0059-0.01)	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 - 4,000 mm (9.84-157.48 in).

Rod and bar

Delivery condition: forged, rolled, drawn, heat-treated, oxidized, de-scaled or pickled, twisted, peeled, ground or polished.

Dimensions*	Outside diameter mm (in)	Length mm (in)
General dimensions	6-800 (0.24-31.5)	1,500-12,000 (59.06-472.44)
Material specific dimensions	10-350 (0.39-13.8)	1,500-12,000 (59.06-472.44)

* Further dimensions on request

Wire

Delivery condition: drawn bright, ¼ hard to hard, bright annealed in rings, containers, on spools and spiders

Drawn mm (in)	Hot rolled mm (in)
0.16-10 (0.006-0.4)	5.5-19 (0.22-0.75)

Other shapes and dimensions such as circular blanks, rings, seamless or longitudinal-welded tubing and forgings can be requested.

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