VDM Metals

A company of ACERINOX

VDM® Alloy K-500
Nicorros Al

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VDM® Alloy K-500 is a nickel-copper alloy that can be age-hardened due to additions of aluminum and titanium. It stands out for its corrosion resistance and high strength even at elevated temperatures. The alloy is non-magnetic. VDM® Alloy K-500 is available in cold or hot-formed condition or with subsequent heat treatment in solution-annealed or age-hardened condition.

VDM® Alloy K-500 is characterized by:

- Excellent corrosion resistance in many applications of offshore engineering and the chemical process industry
- Very good resistance against chloride-induced stress corrosion cracking
- High tensile strength up to 650 °C (1,202 °F) in the age hardened condition
- Good fatigue strength in the age hardened condition
- Non-magnetic down to -100 °C (-148 °F).

Designations and standards

Standard	Material designation
EN	2.4375 - NiCu30Al
ISO	NiCu30Al3Ti
UNS	N05500
AFNOR	NiCu30Al
NA	18

Table 1a – Designations and standards

Designations and standards

Product form	DIN	ASTM	NACE	SAE AMS	Others
Rod, bar, forging	17743 17752 17754	B 865	MR 0103 MR 0175/ ISO 15156	4676	QQ-N-286 Form 1,2

Table 1b – Designations and standards

Chemical composition

	Ni	Fe	C	Mn	Si	Cu	Al	Ti	P	S	Pb	Sn	Zn
Min.	63	0.5				27	2.3	0.35					
Max.		2	0.18	1.5	0.5	33	3.15	0.85	0.02	0.01	0.006	0.006	0.02

Table 2 – Chemical composition (wt.-%)

Physical properties

Density	Relative magnetic permeability at 20 °C (68 °F)	Curie temperature
8.5 g/cm^3 (0.31 lb/in3) at 20 °C (68 °F)	1.0015 (maximum)	Solution-annealed: -135 °C (-211 °F) Solution-annealed and age hardened: -100 °C (-148 °F)

Temperature		Specific heat		Thermal conductivity		Electrical resistivity	Modulus of elasticity		Coefficient of thermal expansion	
°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	10³ ksi	$\frac{10^{-6}}{K}$	$\frac{10^{-6}}{°F}$
-130	-202	323	0.077	13.3	92.3				12.3	6.83
20	68	420	0.100	17.4	120.7	61	179	26.0		
100	212	454	0.108	19.4	134.6	62	178	25.8	13.7	7.61
200	392	480	0.115	20.9	145.0	63	176	25.5	14.6	8.11
300	572	491	0.117	25.1	174.1	65	173	25.1	14.9	8.28
400	762	500	0.119	27.8	192.9	65	168	24.4	15.2	8.44
500	932	517	0.123	30.5	211.6	65	164	23.8	15.5	8.61
600	1,112	538	0.128	33.1	229.7	66	162	23.5	16	8.89
700	1,292	567	0.135	35.7	247.7	66	158	23.0	16.6	9.22
800	1,472	613	0.146	37.4	259.5	67			17	9.44
900	1,652	685	0.164	41.2	285.9	68			17.5	9.72

Table 3 – Typical physical properties at the specified temperatures

Microstructural properties

VDM® Alloy K-500 has a face-centered cubic lattice. In the age hardened condition, the γ' phase is precipitated.

Mechanical properties

The following properties of VDM® Alloy K-500 at room temperature and at elevated temperatures apply to the specified dimensions in the solution-annealed and age hardened condition.

Temperature		**Yield strength** $R_{p\,0.2}$		**Tensile strength** R_m		**Elongation** A
°C	**°F**	**MPa**	**ksi**	**MPa**	**ksi**	**%**
20	68	690	100.1	1,100	159.5	24
100	212	670	97.2	1,040	150.8	
200	392	640	92.8	1,020	147.9	
300	572	620	89.9	980	142.1	
400	762	600	87.0	890	129.1	
500	932	570	82.7	750	108.8	
600	1,112	490	71.1	620	89.9	

Table 4 – Typical short-term properties of solution-annealed and age-hardened VDM® Alloy K-500 at room temperature and at elevated temperatures

Product form	**Dimensions**		**Yield strength** $R_{p\,0.2}$		**Tensile strength** R_m		**Elongation** A
	mm	**in**	**MPa**	**ksi**	**MPa**	**ksi**	**%**
Rod, bar	75-100	2.95-3.94	≥ 655	≥ 95.0	≥ 930	≥ 134.9	≥ 20

Table 5 – Mechanical properties at room temperature according to QQ-N-286; The properties for larger dimensions must be agreed separately.

ISO V-notch impact toughness

Room temperature, age hardened: 68 J/cm^2

Corrosion resistance

The corrosion resistance of VDM® Alloy K-500 is generally equivalent to that of VDM® Alloy 400. The alloy proves excellent resistance against many media, from pure water to highly concentrated salt solutions and alkalis. VDM® Alloy K-500 is virtually immune against stress corrosion cracking induced by chloric ions. In the age hardened condition, the material can be sensitive to stress corrosion cracking in hot hydrofluoric acid vapor under tensions near the yield strength. In fast-flowing sea water and in sea air, good resistance is proven but in hardly moving or standing sea water, pitting can occur. VDM® Alloy K-500 is also very resistant against acid gas media.

Applications

VDM® Alloy K-500 is used in sea water, offshore engineering, in the chemical process and petrochemicals industry and shipbuilding.

Typical applications are:

- Valve seals, pump sleeves and wearing rings in sea water
- Pump shafts and propeller shafts
- Mounting elements/fasteners, e.g. bolts in sea air and splash water zones
- Tug rope armoring
- Springs
- Components of drilling equipment in the oil industry
- Aircraft instrument components

Processing and heat treatment

VDM® Alloy K-500 can be easily processed in both hot and cold forming and can also be 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 K-500. 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 con-tent of maximum 0.5 wt.-% is also suitable with a slightly oxidizing atmosphere. The workpieces may not be contacted directly by flames. Electrical furnaces are to be preferred due to precise temperature control and lack of contaminants due to fuel. The furnace temperature should be set between neutral and slightly oxidizing, and should not change between oxidizing and reducing. The workpieces may not be contacted directly by flames.

Hot forming

VDM® K-500 can be hot-formed in a temperature range from 900 to 1,150 °C (1,652 to 2,102 °F) with subsequent rapid cooling down in water. Cooling down in the air can cause age hardening and then lead to cracks when the material is heated up again. After the hot forming, annealing between 850 and 900 °C (1,562 and 1,652 °F) with subsequent water quenching is recommendable for compensating tensions and any mixed microstructure. The subsequent deformation should be at least 25 % and be implemented below 1,050 °C (1,922 °F) to achieve an optimal toughness.

Cold forming

Cold forming should be conducted on annealed material. VDM® Alloy K-500 has similar forming and strain hardening properties as austenitic stainless steels. This must be taken into account during design and selection of forming tools and equipment and during the planning of forming processes. To achieve a high strength, a combination of cold forming with subsequent age hardening is an option.

Heat treatment

Annealing is conducted in the temperature range from 850 to 1,000 °C (1,562 to 1,832 °F) with retention times between 3 and 5 minutes per mm thickness and preferably in 980 °C (1,796 °F). Temperatures above 1,000 °C (1,832 °F) are not recommendable because strong grain growth can occur. Cooling down in water or accelerated cooling down in the air with thicknesses of less than 3 mm (0.12 in) or diameters of less than 12.5 mm (0.49 in) is recommendable and important so to avoid precipitations. The tension compensation achieved by retention times of 1 to 2 hours at 300 to 350 °C (572 to 662 °F) with subsequent cooling down in the air is necessary to remove the tension concentration from material that has been machined before the age hardening. The tension compensation is also recommendable for material that contains tensions from the cold forming after the last heat treatment, e.g. for straightening. For wire products, the heat treatment can be performed in a continuous furnace at a speed and temperature that is adapted to the wire diameter.

Age hardening

To obtain the highest possible strength values for VDM® Alloy K-500, an age-hardening treatment has to be carried out. It takes place either directly in hot or cold formed condition or following solution annealing. The temperature range for age hardening is between 580 and 610 °C (1,076 and 1,130 °F). The retention times are 3 to 5 hours for flat products, 4 to 16 hours for rods and forgings; cooling down in the furnace is done at approx. 12 °C/h (53.6 °F/h) up to 480 °C (896 °F) with subsequent cooling down in the air. A shortened age hardening can be implemented at 640 °C (1,184 °F) in 2 hours retention time with subsequent cooling down in the furnace for 10 hours at up to 480 °C (896 °F). To determine the best age hardening treatment, it is recommended to conduct a test. In each heat treatment, the aforementioned cleanliness requirements must be observed.

Descaling and pickling

Oxides on VDM® Alloy K-500 and discolorations in the area of weld edges must be removed before use. Before the pickling in hot sulfuric acid, blasting of the surfaces is helpful to shorten the pickling times. Pickling in saltpeter hydrofluoric acid mixtures leads to the formation of nitric gases, damaging health and the environment, and it is therefore not recommendable.

Machining processing

VDM® Alloy K-500 is preferably processed in the annealed condition. The best results in terms of the surface quality of the finished product are achieved, however, by pre-treatment before age hardening and finishing after age hardening. Age hardened material can undergo a heat treatment for the purpose of tension compensation after the finishing. Since the alloy has a tendency to strain hardening, a low cutting speed should be selected and the cutting tool should stay engaged at all times. An adequate chip depth is important in order to cut below a previously formed strain-hardened zone. Optimum heat dissipation through the use of large quantities of suitable, preferably aqueous, lubricants has considerable influence on a stable machining process.

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 C steel is being processed, must be provided. Considerable cleanliness is required, and draughts 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.

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 component surface. Scaling areas are areas in which corrosion more easily occurs.

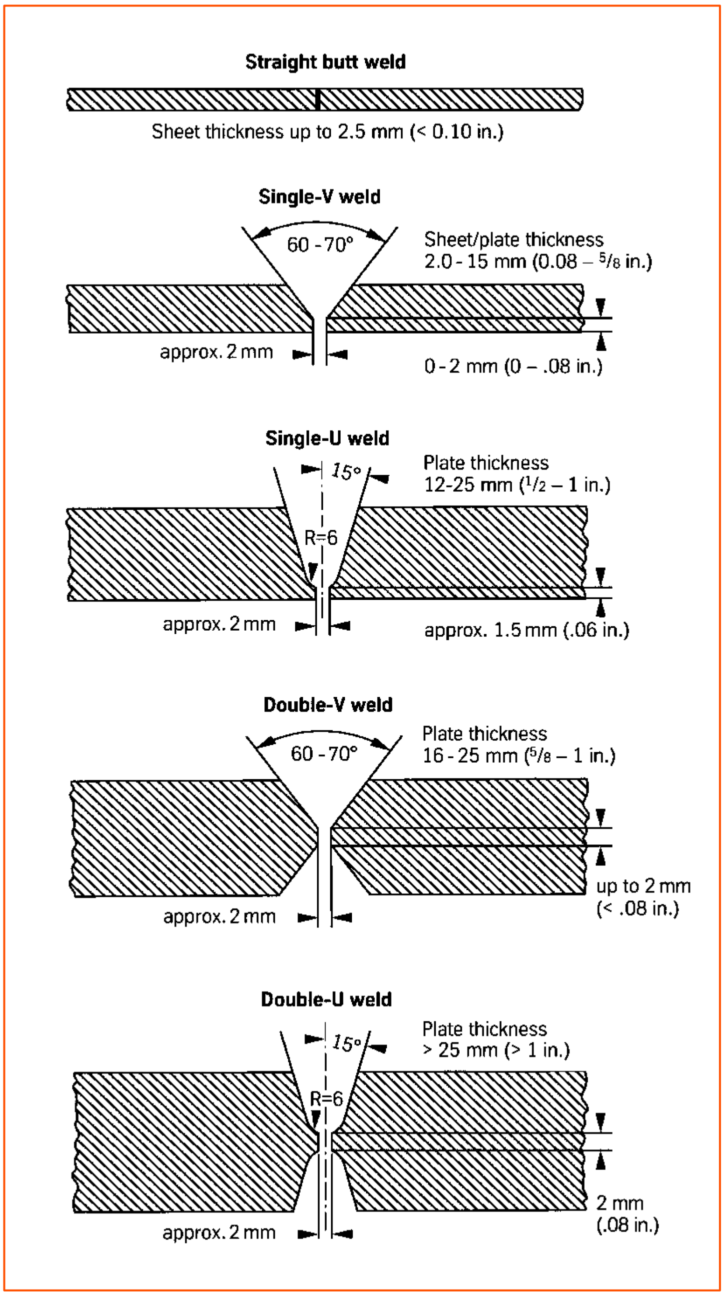

Figure 1 – Seam preparation for welding nickel alloys and special stainless steels

Cleaning

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

Welding technique

The material can be welded using all conventional methods: GTAW (TIG), GTAW (TIG) hot wire, plasma, MIG and submerged arc welding. The material should be in its solution-annealed condition for welding, and should be free of scale, grease and markings. Application of the impulse technique is preferable in gas-shielded metal welding processes. When welding the root, care should be taken to achieve best quality root protection using pure argon (argon 4.6), so that the welding edge is free from oxides after welding the root. Root protection is also recommended for the first and, in certain cases depending on the welded construction, also for the second intermediate layer weld after root welding. Any heat tint must be removed, preferably using a stainless steel brush, while the welding edge is still hot. The interpass temperature should be max. 120 °C (248 °F). After the welding and before the age hardening, it is recommended to anneal the components between 850°C and 900°C (1,562 to 1,652 °F) with subsequent cooling down as quickly as possible.

Filler metal

The following filler material is recommended:

Welding rods, welding wire, and wire electrodes

VDM® FM 60 (W.-Nr. 2.4377)
DIN EN ISO 18274: S Ni 4060 (NiCu30Mn3Ti)
UNS N04060
AWS A5.14: ERNiCu-7

The use of covered electrodes is possible.

Post-weld treatment

During optimum implementation of the work, brushing directly after welding, in a hot condition, without additional pickling, results in the desired surface condition; this means that heat tint can be removed completely. Once the welding work is finished, age hardening can be conducted to achieve a maximum of strength. 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.

Availability

VDM® Alloy K-500 is available in the following standard semi-finished product forms:

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 (0.24-31.5)	1,500-12,000 (59.06-472.44)
Material specific dimensions	12-450 (0.47-17.7)	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 available on request.

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