

VDM® Alloy 800 H/HP
Nicrofer 3220 H/HP

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VDM® Alloy 800 H is an austenitic, heat resistant iron-nickel -chromium alloy with controlled levels of carbon, aluminum and titanium.

The analysis of VDM® Alloy 800 H is identical to that of VDM® Alloy 800. A special solution annealing results in a grain sizes $\geq 90 \mu\text{m}$ (ASTM No. 4), which increases the creep rupture strength above $600 \text{ }^\circ\text{C}$ ($1,112 \text{ }^\circ\text{F}$) significantly.

VDM® Alloy 800 H is characterized by:

- good creep rupture strength at temperatures above $600 \text{ }^\circ\text{C}$ ($1,112 \text{ }^\circ\text{F}$)
- good resistance in oxidizing, nitriding and carburizing conditions
- metallurgical stability in long-term use at high temperatures

VDM® Alloy 800 HP is an austenitic nickel-iron-chromium alloy with increased content of (Al + Ti), compared to VDM® Alloy 800 H.

A special solution annealing results in a grain sizes $\geq 90 \mu\text{m}$ (ASTM No. 4) and highest creep rupture strength above $700 \text{ }^\circ\text{C}$ ($1,290 \text{ }^\circ\text{F}$) due to titanium carbide precipitation. Below $700 \text{ }^\circ\text{C}$ ($1,290 \text{ }^\circ\text{F}$), γ' precipitates combined with a loss of ductility.

VDM® Alloy 800 HP is characterized by:

- excellent creep rupture strength at temperatures above $700 \text{ }^\circ\text{C}$ ($1,290 \text{ }^\circ\text{F}$)
- good resistance to reducing, oxidizing and nitriding atmospheres and to atmospheres which alternate between reducing and oxidizing conditions
- metallurgical stability in long-term use at high temperatures

If the repeated lowering of operating temperatures below $700 \text{ }^\circ\text{C}$ ($1,290 \text{ }^\circ\text{F}$) cannot be ruled out, or the operating temperature is permanently below $700 \text{ }^\circ\text{C}$ ($1,290 \text{ }^\circ\text{F}$), the use of VDM® Alloy 800 H is recommended. At temperatures below $600 \text{ }^\circ\text{C}$ ($1,112 \text{ }^\circ\text{F}$), soft annealed VDM® Alloy 800 is generally used.

Designations and standards

| Standard | Material designation | |
|----------|---|--|
| | VDM® Alloy 800 H | VDM® Alloy 800 HP |
| EN | 1.4876 - X10NiCrAlTi32-20 ¹⁾ 1.4958 - X5NiCrAlTi31-20 ²⁾ | 1.4959 - X8NiCrAlTi32-21 ²⁾ |
| ISO | FeNi32Cr21AlTi-HC | FeNi32Cr21AlTi-HT |
| UNS | N08810 | N08811 |
| AFNOR | | Fe-Ni29Cr17 |
| NA | 15 (H) | |

¹⁾ VdTÜV data sheet 412, version 01.84 with old W.-No. 1.4876

²⁾ W.-No. according to DIN EN 10302

Table 1a – Designations and standards

Designations and standards

| Product form | DIN | DIN EN | ISO | ASTM | ASME | VdTÜV | SEW | Others |
|--------------|-----|---------------------|------|-------|--------|-------------------|-----|-----------------------------------|
| Sheet, plate | | 10028-7 | | A 240 | SA 240 | 412 | | ASME Code Case 1325 ¹⁾ |
| | | 10095 ¹⁾ | | B 409 | SB 409 | 434 ¹⁾ | | NACE MR 0175/ISO 15156 |
| | | 10302 | | | | | | |
| Strip | | 10028-7 | 6208 | A 240 | SA 240 | 412 | 470 | SAE AMS 5871 ²⁾ |
| | | 10088-1 | | B 409 | SB 409 | 434 ¹⁾ | | |
| | | 10095 | | | | | | |
| Rod, bar | | 10095 ¹⁾ | | B 408 | SB 408 | 412 | 470 | |
| | | 10302 | | B 564 | SB 564 | 434 ¹⁾ | | |

¹⁾ only valid for VDM® Alloy 800 H

²⁾ only valid for VDM® Alloy 800 HP

Table 1b – Designations and standards

Chemical composition

VDM® Alloy 800 H

| | Ni | Cr | Fe | C | Mn | Si | Cu | Al | Ti | P | S | (Al + Ti) |
|------|----|----|----|------|-----|-----|-----|-----|-----|-------|------|-----------|
| Min. | 30 | 19 | 43 | 0,06 | 0,5 | 0,2 | | 0,2 | 0,2 | | | |
| Max. | 32 | 21 | 50 | 0,1 | 1 | 0,6 | 0,5 | 0,6 | 0,6 | 0,015 | 0,01 | 0,7 |

Table 2b – Chemical composition (wt.-%) of VDM® Alloy 800 H

VDM® Alloy 800 HP

| | Ni | Cr | Fe | C | Mn | Si | Cu | Al | Ti | P | S | (Al + Ti) |
|------|----|----|----|------|-----|-----|-----|-----|-----|-------|------|-----------|
| Min. | 30 | 19 | 43 | 0,06 | 0,5 | 0,2 | | 0,2 | 0,3 | | | 0,85 |
| Max. | 32 | 22 | 50 | 0,1 | 1 | 0,6 | 0,5 | 0,6 | 0,6 | 0,015 | 0,01 | 1,2 |

Table 2b – Chemical composition (wt.-%) of VDM® Alloy 800 HP

Physical properties

| Density | Melting range | Relative magnetic permeability at 20 °C (68 °F) |
|--|---------------------------------|---|
| 8.0 g/cm ³ (0.29 lb/in ³) at 20 °C (68 °F) | 1,350-1,400 °C (2,462-2,552 °F) | 1.01 |

| Temperature | | Specific heat | | Thermal conductivity | | Electrical resistivity | Modulus of elasticity | | Coefficient of thermal expansion | |
|-------------|-------|---------------|---------|----------------------|-----------------|------------------------|-----------------------|---------------------|----------------------------------|------------------|
| °C | °F | K | Btu | W | Btu · in | μΩ · cm | GPa | 10 ³ ksi | 10 ⁻⁶ | 10 ⁻⁶ |
| | | Kg · K | lb · °F | m · K | sq. ft · h · °F | | K | °F | | |
| 20 | 68 | 443 | 0.106 | 12.4 | 86 | 101 | 194 | 28.1 | 14 | 7.78 |
| 100 | 212 | 457 | 0.109 | 13.7 | 95.1 | 104 | 189 | 27.4 | 14.08 | 7.82 |
| 200 | 392 | 474 | 0.113 | 15.3 | 106.2 | 108 | 183 | 26.5 | 14.6 | 8.11 |
| 300 | 572 | 492 | 0.118 | 17 | 117.9 | 112 | 177 | 25.7 | 14.92 | 8.28 |
| 400 | 762 | 512 | 0.122 | 18.9 | 131.1 | 115 | 170 | 24.7 | 15.2 | 8.44 |
| 500 | 932 | 548 | 0.131 | 21.4 | 148.5 | 118 | 163 | 23.6 | 15.49 | 8.61 |
| 600 | 1,112 | 578 | 0.138 | 23.6 | 163.7 | 120 | 156 | 22.6 | 15.87 | 8.82 |
| 700 | 1,292 | 588 | 0.140 | 24.7 | 171.4 | 122 | 149 | 21.6 | 16.42 | 9.12 |
| 800 | 1,472 | 598 | 0.143 | 25.8 | 179 | 124 | 141 | 20.5 | 16.98 | 9.43 |
| 900 | 1,652 | 602 | 0.144 | 26.7 | 185.2 | 126 | 134 | 19.4 | 17.36 | 9.64 |
| 1,000 | 1,832 | 613 | 0.146 | 28 | 194.3 | 127 | 127 | 18.4 | 17.76 | 9.87 |
| 1,100 | 2,012 | 628 | 0.150 | 29.6 | 205.4 | 128 | 120 | 17.4 | 18.27 | 10.15 |
| 1,200 | 2,192 | 634 | 0.151 | 30.6 | 212.3 | 129 | 113 | 16.4 | 18.74 | 10.41 |

Table 3 – Typical physical properties of VDM® Alloy 800 Hat room temperature and elevated temperatures

Microstructural properties

VDM® Alloy 800, VDM® Alloy 800 H and VDM® Alloy 800 HP are austenitic solid solution alloys which precipitate carbides and γ' phase during high temperature ageing.

Mechanical properties

The following properties are applicable to VDM® Alloy 800 H and VDM® Alloy 800 HP in the annealed condition in the following size ranges:

- Sheet, plate up to 50 mm (1.97 in)
- Strip up to 3 mm (0.12 in)
- Rod, bar and forgings up to 250 mm (9.84 in)

For larger dimensions, the properties are to be agreed separately. The values are valid for longitudinal and transverse samples.

| Temperature | | Yield strength $R_{p0.2}$ | | Tensile strength R_m | | Elongation A |
|-------------|-------|------------------------------|------|---------------------------|------------|-----------------------------|
| °C | °F | MPa | ksi | MPa | ksi | % |
| 20 | 68 | 170 | 24.7 | 450-700 | 65.3-101.5 | Longit. 35 Transverse 30 |
| 100 | 212 | 140 | 20.3 | 425 ¹⁾ | 61.6 | |
| 200 | 392 | 115 | 16.7 | 400 ¹⁾ | 58 | |
| 300 | 572 | 95 | 13.8 | 390 ¹⁾ | 56.6 | |
| 400 | 762 | 85 | 12.3 | 380 ¹⁾ | 55.1 | |
| 500 | 932 | 80 | 11.6 | 360 ¹⁾ | 52.2 | |
| 600 | 1,112 | 75 | 10.9 | 300 ¹⁾ | 43.5 | |

¹⁾ Average, for information only

Table 4 – Mechanical short-time properties of solution annealed VDM® Alloy 800 H and VDM® Alloy 800 HP at room temperature and elevated temperatures; min. values according to VdTÜV data sheet 412

| Product form | Dimensions mm | Yield strength | Tensile strength | Elongation |
|---------------------|------------------|-------------------|------------------|------------|
| | | $R_{p0.2}$ MPa | R_m MPa | A % |
| Sheet, plate, strip | ≤ 50 | ≥ 170 | 450-700 | ≥ 30 |
| Rod, bar | ≤ 160 | ≥ 170 | 450-700 | ≥ 30 |
| Forging | ≤ 250 | ≥ 170 | 450-700 | ≥ 30 |

Table 5 – Mechanical properties at room temperature according to VdTÜV data sheet 412

ISO V-notch impact toughness

Average values at room temperature, longit.: 150 J/cm²

Average values at room temperature, transverse: 100 J/cm²

| Temperature | | Creep strength $R_m/10^5$ h | | | |
|-------------|-------|-----------------------------|--------------------------|-----------|-----------|
| | | UNS N08810 ¹⁾ | UNS N08811 ¹⁾ | VdTÜV 412 | VdTÜV 434 |
| °C | °F | MPa | MPa | MPa | MPa |
| 600 | 1,112 | 114 | | 114 | 77 |
| 650 | 1,202 | 75 | | 73 | 53 |
| 700 | 1,292 | 50 | 57 | 47 | 36 |
| 750 | 1,382 | 33 | 37 | 30 | 24 |
| 800 | 1,472 | 22 | 26 | 19 | 16 |
| 850 | 1,562 | 15 | 18 | 10 | 10.5 |
| 900 | 1,652 | 10 | 11 | 4 | 7 |
| 950 | 1,742 | | 7 | | |

¹⁾ VDM Metals calculation, based on ASME Code Case 1987; for 950 °C (1,742 °F) based on ASME Code Case 1988

Table 6 – $R_m/10^5$ h creep rupture strength

Corrosion resistance

The high nickel and chromium contents in VDM® Alloy 800 H and VDM® Alloy 800 HP ensure excellent resistance to oxidation. The alloys are also highly resistant to carburizing, nitriding and oxidation in sulphurous atmospheres. The protective oxide layer is adherent under static and cyclic thermal stress. Both materials are particularly resistant to carburization if a thin oxide film was formed by pre-oxidation.

The resistance to hydrogen embrittlement of VDM® Alloy 800 H and 800 HP is excellent, so that the alloys can be used in the production of hydrogen and steam/hydrocarbon reformers.

Applications

VDM® Alloy 800H and Alloy 800 HP have a wide range of applications in areas of elevated temperatures in furnace construction, in the chemical industry, in environmental protection equipment, in the automotive industry and in power plants. Typical applications include furnace muffles, containers, bins, holders in various heat treatment plants and burner components.

Because of their resistance to carburization and nitriding, the alloys are furthermore used in the areas of:

- steam/hydrocarbon reformers
- ethylene pyrolysis
- Equipment for acetic anhydride and ketone production.

Fabrication and heat treatment

VDM® Alloy 800 H and Alloy 800 HP 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 800 H and Alloy 800 HP. 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. Reducing or changing furnace atmosphere should be avoided, as well as direct flame impingement. The temperature should be precisely controlled.

Hot working

VDM® Alloy 800 H and Alloy 800 HP may be hot-worked in the temperature range 1,200 to 900 °C (2,192 to 1,650 °F) with subsequent rapid cooling down in water or by using air. In particular the temperature range from 760 to 540 °C (1,400 to 1,004 °F) must be passed quickly. Hot bending is carried out at 1,150 to 1,000 °C (2,102 to 1,832 °F). The furnace should be heated up to maximum working temperature (1,200 °C/2,192 °F) before workpieces are inserted into the preheated furnace. The holding time is about 60 minutes per 100 mm thickness. After the hot forming a solution heat treatment is recommended in order to achieve optimum creep strength.

Cold working

Cold working should be carried out on annealed material. VDM® Alloy 800 H and Alloy 800 HP have 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. Intermediate annealing may be necessary at high degrees of cold working deformation.

After cold working with more than 10 % deformation the material should be solution annealed.

Heat treatment

Solution heat treatment should be carried out at the following temperatures:

- VDM® Alloy 800 H: 1,150 °C (2,102 °F)
- VDM® Alloy 800 HP: 1,150 bis 1,200 °C (2,102 to 2,192 °F)

The retention time during annealing depends on the workpiece thickness and can be calculated as follows:

- For thicknesses $d \leq 10$ mm (0.4 in) the retention time is $t = d \cdot 3$ min/mm
- For thicknesses $d = 10$ to 20 mm (0.4 to 0.8 in) the retention time is $t = 30$ min + $(d - 10)$ mm $\cdot 2$ min/mm
- For thicknesses $d > 20$ mm (0.8 in) the retention time is $t = 50$ min + $(d - 20)$ mm $\cdot 1$ min/mm

The retention time starts when the annealing temperature is reached. Longer retention times are less critical than too short retention times.

Water quenching should be carried out rapidly if the material should be further fabricated after solution annealing. Workpieces of less than 3 mm (0.12 in) thickness can be cooled down using air nozzles. If the solution annealing is the last fabrication step, the material can be cooled down more slowly in order to avoid material distortion.

Solution annealed VDM® Alloy 800 H and 800 HP are prone to stress relaxation cracks in the temperature range of 550 and 750 °C and should therefore be subjected to stabilizing annealing when a continuous operation (> 100 h) in the mentioned temperature range is intended. The stabilizing annealing temperature depends on the welding material and

should be determined with VDM Metals' Technical Customer Support. If possible, the stabilizing annealing should be carried out when all welding work is completed, because the heat-affected zones of the welds are particularly susceptible to cracking. Heating rates are critical and should not be too high to avoid distortion.

For strip and wire products, the heat treatment can be performed in a continuous furnace at a speed and temperature that is adapted to the material thickness. The cleanliness requirements listed under 'Heating' must be complied with.

Descaling and pickling

High temperature alloys develop a protective oxide layer in service. Therefore the necessity of descaling should be checked during the order process. Oxides of VDM® Alloy 800 H and 800 HP 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 should preferably be carried out in nitric hydrofluoric acid, oxide and scale layers have to be disrupted by blasting or treated in oxidizing salt melts. The pickling baths used must carefully be monitored regarding the concentration and temperatures; through too long pickling times, the material surface may be damaged by intergranular corrosion.

Machining

VDM® Alloy 800 H and 800 HP should be machined in the solution annealed condition. As the alloys are prone to work-hardening, low cutting speeds and appropriate feed rates should be used and the tool should be engaged at all times. Sufficient chip depths are important to get below the work-hardened surface layer.

Due to the high temperature loads on the cutting edge during machining, large amounts of cooling lubricants should be used. Water-based emulsions, as they are also used for construction and stainless steels, are suitable for instance.

Welding

When welding nickel-base alloys and special stainless steels, the following instructions should be adhered to:

Workplace

A separately-located workplace, which is specifically separated from areas in which carbon steels are being processed, should be used. Maximum cleanliness is required, and draughts should be avoided during inert gas welding.

Auxiliary equipment and clothing

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

Tools and machines

Tools used for other materials must not be used for nickel-base alloys and stainless steels. Brushes should be made of stainless materials. Processing and machining equipment such as shears, punches or rollers must be fitted with means (felt, cardboard, films) in order to avoid material contamination with ferrous particles, which can be pressed into the surface of the material and thus lead to corrosion.

Welding edge preparation

Welding edge preparation should preferably be carried out using mechanical methods such as lathing, milling or planing. Abrasive waterjet cutting or plasma cutting is also suitable. In the latter case, however, the cut edge (seam flank) must be cleanly re-worked. Careful grinding without overheating is also acceptable.

Ignition

The arc may only be struck in the weld area, e.g. along the seam flanks or outlets, and should not be carried out on the workpiece surface. Arc striking areas are prone to corrosion.

Included angle

The different physical characteristics of nickel alloys and special stainless steels are generally reflected through lower thermal conductivity and higher thermal expansion in comparison with carbon steel. This should be allowed for by means of, among other things, wider root gaps or openings (1-3 mm; 0.04-1.2 in), while larger included angles (60-70°), as shown in Fig. 1, should be used for individual butt joints owing to the viscous nature of the molten weld metal and to counteract the pronounced shrinkage tendency.

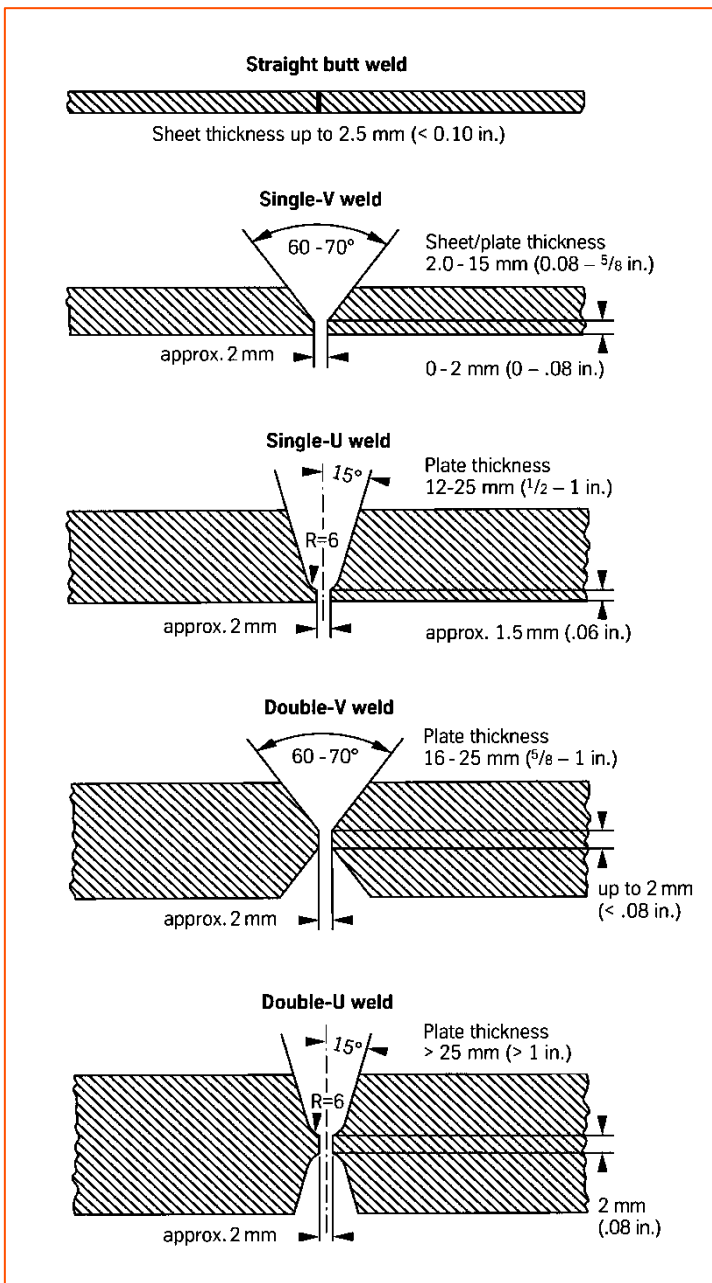


Figure 1 – Edge preparation for welding nickel alloys and special stainless steels

Cleaning

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

Welding process

For welding, VDM® Alloy 800 H and 800 HP should be in the annealed condition and be free from scale, grease and markings. VDM® Alloy 800 H and 800 HP can be welded using the following procedures: GTAW (TIG), GTAW (TIG) hot wire, plasma, SMAW (MMA), GMAW (MIG/MAG) and submerged arc welding.

Filler metal

The following filler materials are recommended:

VDM® FM 82 (W.-Nr. 2.4806)

DIN EN ISO 18274: S Ni 6082 (SG/UP-NiCr 20 Nb)

AWS A 5.14: ERNiCr-3

The use of covered electrodes is possible.

Welding parameters and influences

Care should be taken that the work is performed with a deliberately chosen, low heat input as indicated in Table 7 by way of example. The stringer bead technique is recommended. In this context attention should also be drawn to the correct selection of wire and electrode diameters. The corresponding section energies are exemplified in Table 7 below. The interpass temperature should not exceed 120 °C (248 °F). The welding parameters should be monitored as a matter of principle.

The heat input Q may be calculated as follows:

$$Q = \frac{U \cdot I \cdot 60}{v \cdot 1.000} \left(\frac{\text{kJ}}{\text{cm}} \right)$$

U = arc voltage, volts

I = welding current, amps

v = welding speed, cm/min.

Post-weld 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. Please also refer to the information on 'Descaling and pickling'. Neither pre- nor postweld heat treatments are required.

| Thickness (mm) | Welding technique | Filler material | | Root pass ¹⁾ | | Intermediate and final passes | | Welding speed (cm/min) | Shielding gas | |
|-------------------|--------------------------------|------------------|------------------|-------------------------|----------|----------------------------------|----------|------------------------------|--------------------------|-----------------|
| | | Diameter (mm) | Speed (m/min) | I in (A) | U in (V) | I in (A) | U in (V) | | Type | Rate (l/min) |
| 3 | manual TIG | 2 | - | 90 | 10 | 110-120 | 11 | 10-15 | I1, R1 mit max. 3% H2 | 8-10 |
| 6 | manual TIG | 2-2,4 | - | 100-110 | 10 | 120-130 | 12 | 10-15 | I1, R1 mit max. 3% H2 | 8-10 |
| 8 | manual TIG | 2,4 | - | 110-120 | 11 | 130-140 | 12 | 10-15 | I1, R1 mit max. 2% H2 | 8-10 |
| 3 | autom. TIG HD ²⁾ | 0,8-1,2 | 1-2,5 | - | - | 150 | 10 | 25 | I1, R1 mit max. 2% H2 | 15-20 |
| 5 | autom. TIG HD ²⁾ | 0,8-1,2 | 1-2,5 | - | - | 150 | 10 | 25 | I1, R1 mit max. 2% H2 | 15-20 |
| 6 | Plasma ³⁾ | 1,0-1,2 | 1 | 165 | 25 | - | - | 25 | I1, R1 mit max. 2% H2 | 30 |
| 8 | Plasma ³⁾ | 1,0-1,2 | 1 | 190-200 | 25 | - | - | 30 | I1, R1 mit max. 2% H2 | 30 |
| 8 | GMAW ⁴⁾ | 1 | 8 | - | - | 140-160 | 25-28 | 25-30 | I1, R1 mit max. 2% H2 | 18-20 |
| ≥ 10 | GMAW ⁴⁾ | 1,2 | 5 | - | - | 150 | 23-27 | - | I1, R1 mit max. 2% H2 | 18-20 |
| ≥ 12 | Submerged arc welding | 1,6 | - | - | - | 250 | 28 | 44-55 | - | - |

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

⁴⁾ For MAG welding the use of multicomponent inert gases is recommended.

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 800 H and HP are available in the following standard semi-finished product forms:

Sheet and plate

Delivery conditions: hot or cold rolled, heat treated, descaled 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 (39.37-98.43) | ≤ 5,500 (216.54) | – |
| Hot rolled* | 3-80 (0.12-3.15) | ≤ 2,500 (39.37-98.43) | ≤ 12,000 (472.44) | ≤ 2,250 |

* 2 mm thickness on request

Strip

Delivery conditions: cold rolled, heat treated, pickled or bright annealed

| Thickness mm (in) | Width mm (in) | Coil - inside diameter mm | | | |
|------------------------------|-----------------------|------------------------------|-----|-----|-----|
| 0.02-0.15 (0.0008-0.0059) | 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 |

Rod and bar

Delivery conditions: forged, rolled, drawn, heat treated, oxidised, descaled resp. pickled, machined, 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 | 12-500 (0.47-19.69) | 1,500-12,000 (59.06-472.44) |

* Further dimensions on request

Wire

Delivery conditions: bright drawn, 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 tubes and pipes or forgings are subject to special enquiry.

Technical publications

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Imprint

Date of publication

23 November 2020

Publisher

VDM Metals GmbH
Plettenberger Straße 2
58791 Werdohl
Germany

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