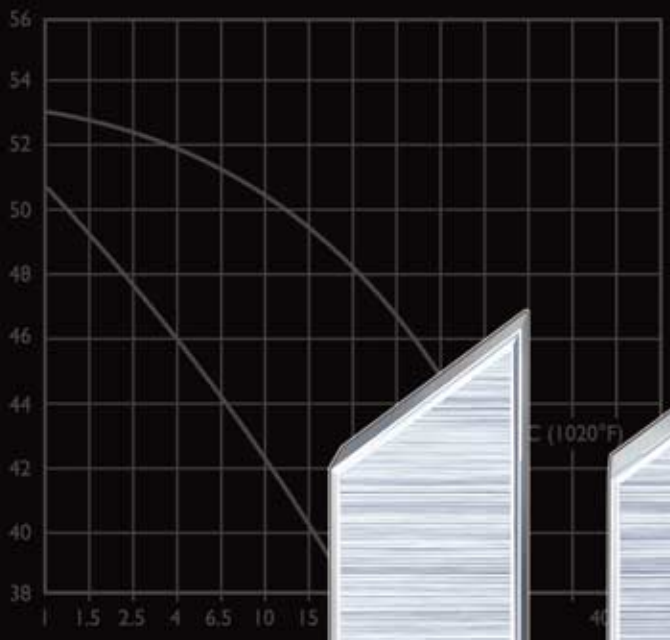
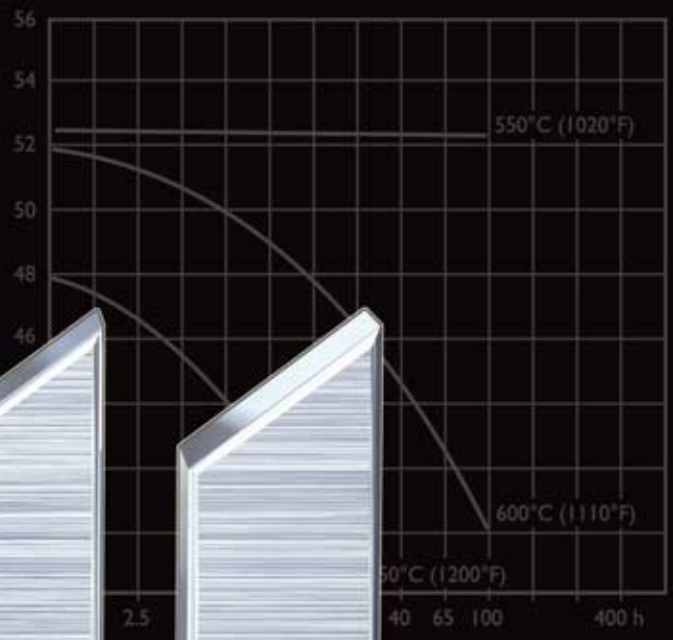
VANADIS 23

High performance powder metallurgical steel for cutting tools

COLD WORK | **PLASTIC** MOULDING | **HOT** WORK | **HIGH** PERFORMANCE STEEL





Typical analysis %	C 2,05					Mn 0,8	Cr 4,5	W 0,2
Standard specifikation	AISI D6, (							03) (W.Nr. 1.2796)
Delivery condition	Soft anne							o approx. 200 HB
Colour code	Red							

Temperature	20°C (68°F)			200°C (390°F)	400°C (750°F)
Density kg/m³ lbs/m³	7 770 0,281			7 650 0,276	7 650 0,275
Modulus of elasticity N/mm² psi	194 000 28,1 x 10⁶	188 000 27,3 x 10⁶		194 000 28,1 x 10⁶	189 000 27,4 x 10⁶	173 000 25,1 x 10⁶
Coefficient of thermal expansion per °C from 20°C per °F from 68°F	to 100°C 11,7 x 10⁶ to 212°F 6,5 x 10⁶	to 200°C 12 x 10⁶ to 400°F 6,7 x 10⁶	to 400°C 13,0 x 10⁶ to 750°F 7,3 x 10⁶	to 100°C 12,3 x 10⁶ to 212°F 6,1 x 10⁶	to 200°C 14 x 10⁶ to 400°F 6,7 x 10⁶	to 400°C 15,1 x 10⁶ to 750°F 7,3 x 10⁶
Thermal conductivity W/m °C Btu in (ft²h°F	- -	27 187	32 221	20,5 142	21,5 149	23,0 159
Specific heat K/kg °C Btu/lbs °F	455 0,109	525 0,126	608 0,145	460 0,110	-	-

Critical tool steel properties for

High wear resistance is often associated with low toughness and vice-versa. However, in many cases both high wear resistance and toughness are essential for optimal tooling performance.

VANADIS 23 is a powder metallurgical tool steel offering an excellent combination of wear resistance and toughness suitable for most cutting tool applications.

TOOLMAKING

The powder manufacturing route used for *VANADIS 23* means that its machinability is superior to that of similar conventionally produced high speed steel grades.
The dimensional stability of *VANADIS 23* in heat treatment is excellent and predictable compared to conventionally produced high alloy steels. This, coupled with its high hardness, good toughness and high temperature tempering, means that *VANADIS 23* is very suitable for surface coating, in particular for PVD.

Applications

VANADIS 23 is suitable for cutting tools such as reamers, taps, milling cutters, broaches etc. *VANADIS 23* is in this context an allround steel to be used in cutting conditions with high demands on wear resistance and toughness where hot hardness is not a major demand.

General

VANADIS 23 is a chromium-molybdenum-tungsten-vanadium alloyed high speed steel which is characterized by:

- High wear resistance (abrasive profile)
- High compressive strength
- Very good through-hardening properties
- Good toughness
- Very good dimensional stability on heat treatment
- Very good temper resistance.

Typical analysis %	C 1,28	Cr 4,2	Mo 5,0	W 6,4	V 3,1
Standard specification	AISI M3:2/W.-Nr. 1.3344				
Delivery condition	Soft annealed to max. 270* HB				
Colour code	Violet				

* For drawn material max. 300 HB

Properties

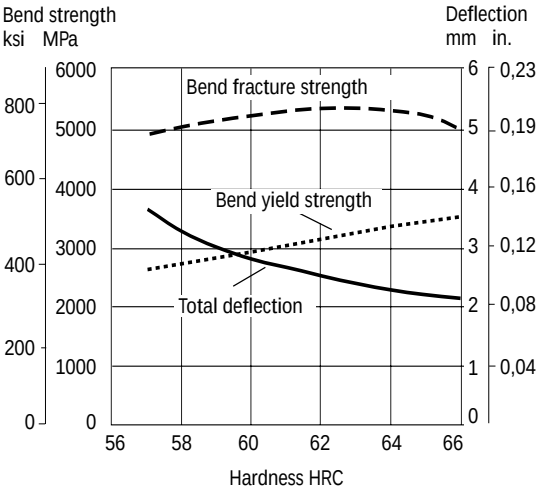
PHYSICAL DATA

Hardened and tempered condition.

Temperature	20°C (68°F)	400°C (750°F)	600°C (1110°F)
Density kg/m^3 lbs/in^3	 7980 0,287	 7870 0,283	 7805 0,281
Modulus of elasticity MPa ksi	 230 000 33 x 10^3	 205 000 30 x 10^3	 184 000 27 x 10^3
Coefficient of thermal expansion per °C from 20°C °F from 68°F	 – –	 12,1 x 10^{-6} 6,7 x 10^{-6}	 12,7 x 10^{-6} 7,0 x 10^{-6}
Thermal conductivity W/m•°C Btu in/ft^2 h °F	 24 166	 28 194	 27 187
Specific heat J/kg °C Btu /lb °F	 420 0,10	 510 0,12	 600 0,14

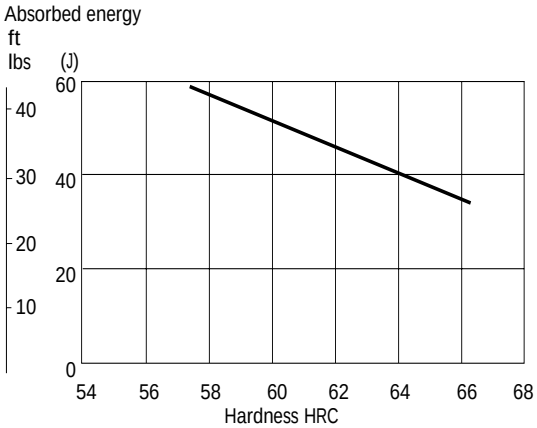
BEND STRENGTH AND DEFLECTION

Four-point bend testing.
Specimen size: 5 mm (0,2") Ø.
Loading rate: 5 mm/min. (0,2"/min.).
Austenitizing temperature: 990–1180°C (1810–2160°F).
Tempering: 3 x 1 h at 560°C (1040°F).



IMPACT STRENGTH

Approximate room temperature impact strength at different hardness levels.
Specimen size: 7 x 10 x 55 mm (0,27" x 0,40" x 2,2").
Specimen type: unnotched.
Tempering: 3 x 1 h at 560°C (1040°F).
Longitudinal direction.



Heat treatment

SOFT ANNEALING

Protect the steel and heat through to 850–900°C (1560–1650°F). Then cool in the furnace at 10°C/h (20°F/h) to 700°C (1290°F), then freely in air.

STRESS RELIEVING

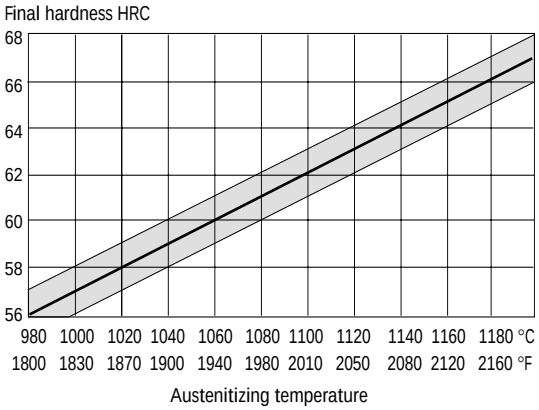
After rough machining the tool should be heated through to 600–700°C (1110–1290°F), holding time 2 hours. Cool slowly to 500°C (930°F), then freely in air.

HARDENING

Pre-heating temperature: 450–500°C (840–930°F) and 850–900°C (1560–1650°F).

Austenitizing temperature: 1050–1180°C (1920–2160°F) according to the desired final hardness, see figure below.

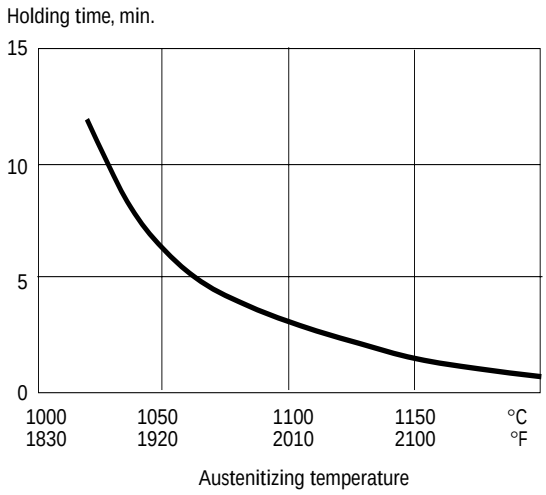
The tool should be protected against decarburization and oxidation during hardening.



Hardness after different hardening temperatures and tempering 3 times for 1 hour at 560°C (1040°F).

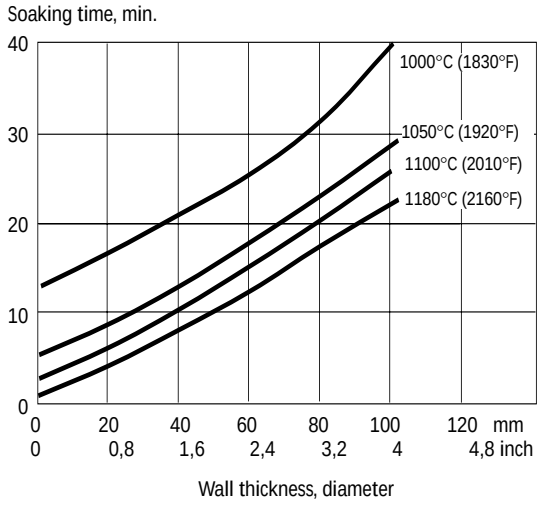
HRC	°C	°F
58	1020	1868
60	1060	1940
62	1100	2012
64	1140	2084
66	1180	2160

Recommended holding time, fluidized bed, vacuum or atmosphere furnace



Note: Holding time = time at austenitizing temperature after the tool is fully heated through.

Total soaking time in a salt bath after pre-heating in two stages at 450°C (840°F) and 850°C (1560°F)



QUENCHING MEDIA

- Vacuum furnace with high speed gas at sufficient overpressure (2–5 bar)
- Martempering bath or fluidized bed at approx. 550°C (1020°F)
- Forced air/gas.

Note 1: Quenching should be continued until the temperature of the tool reaches approx. 50°C (120°F). The tool should then be tempered immediately.
Note 2: For applications where maximum toughness is required use a martempering bath or a furnace with sufficient overpressure.

TEMPERING

Tempering should always be carried out at 560°C (1040°F) irrespective of the austenitizing temperature. Temper three times for one hour at full temperature. The tool should be cooled to room temperature between the tempers. The retained austenite content will be less than 1% after this tempering cycle.

DIMENSIONAL CHANGES

Dimensional changes after hardening and tempering.
Heat treatment: Austenitizing between 1050–1130°C (1920–2070°F) and tempering 3 x 1 h at 560°C (1040°F).
Specimen size: 80 x 80 x 80 mm (3" x 3" x 3") and 100 x 100 x 25 mm (4" x 4" x 1").
Dimensional changes: growth in length, width and thickness +0,03% – +0,13%.

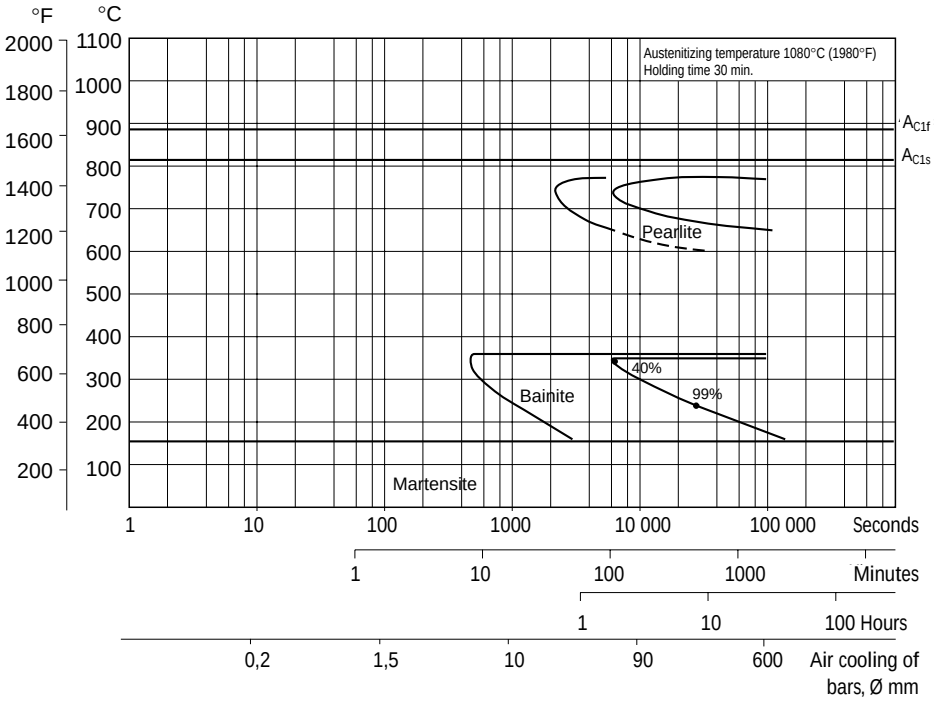
SUB-ZERO TREATMENT

Pieces requiring maximum dimensional stability can be sub-zero treated as follows:
Immediately after quenching the piece should be sub-zero treated to between –70 to –80°C (–95 and –110°F), soaking time 1–3 hours, followed by tempering. Sub-zero treatment will give a hardness increase of ~1 HRC. Avoid intricate shapes as there will be risk of cracking.

Some guidelines for hardening

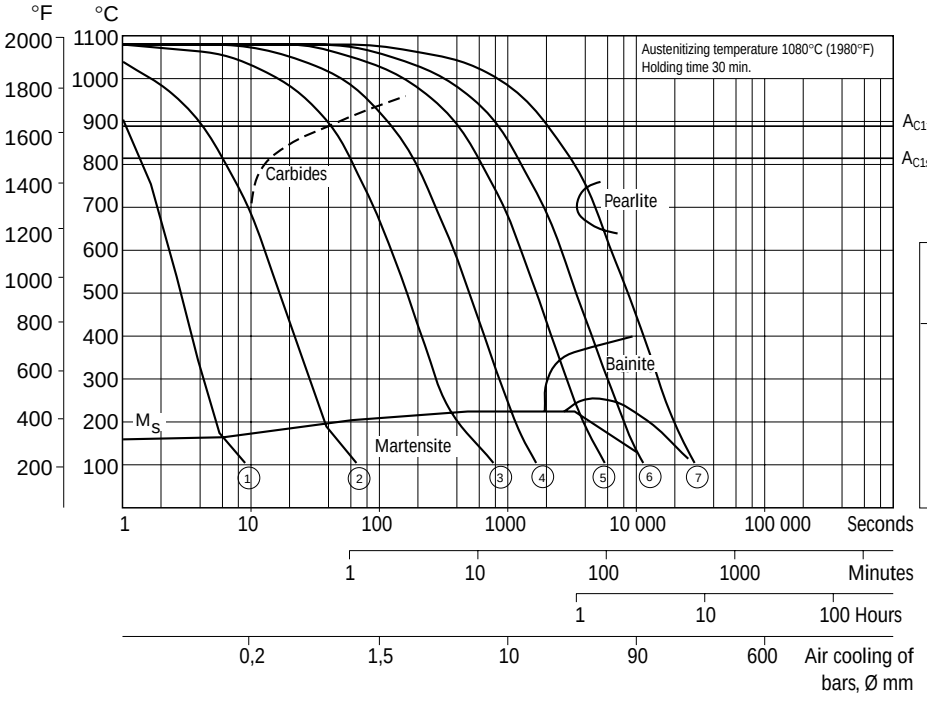
Tool	*VANADIS 23*		
	Hardening	Tempering 3 times	HRC
Single-edge tools: tool bits, form tools, etc.	1180°C 2155°F	560°C 1040°F	65–66
Rotating multi-edge tools: twist drills, milling cutters, broaches, taps etc.	1150–1180°C 2100–2155°F	560°C 1040°F	64–66

TTT-graph (isothermal transformation).
Austenitizing temperature 1080°C (1980°F). Holding time 30 minutes.



Temp. °C	Time hours	Hardness HV 10
775	16,9	276
750	2,5	363
725	2,2	370
700	4,5	380
650	70,7	370
600	17,7	813
400	23,0	907
375	23,3	907
350	2,1	649
300	2,7	613
250	22,5	665
200	25,8	707

CCT-graph (continuous cooling).
Austenitizing temperature 1080°C (1980°F). Holding time 30 minutes.

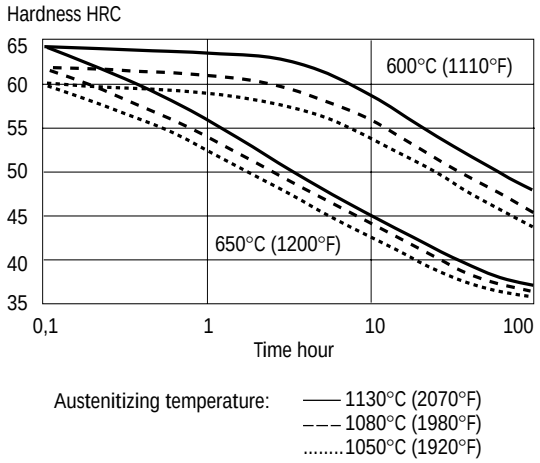


Cooling curve No.	Hardness HV 10	$T_{800–500}$ (sec)
1	907	1
2	894	10
3	894	104
4	858	313
5	803	1041
6	673	2085
7	530	5211

HIGH TEMPERATURE PROPERTIES
TEMPERING RESISTANCE

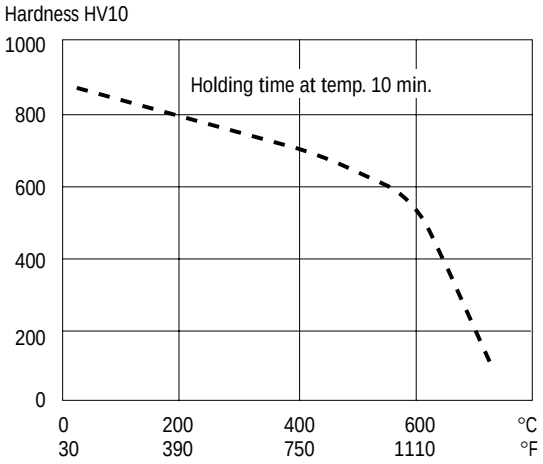
Hardness as a function of holding time at different working temperatures.

Austenitizing temperature: 1050–1130°C (1920–2070°F). Tempering: 3 x 1 h at 560°C (1040°F).



Hot hardness

Austenitizing temperature: 1180°C (2160°F). Tempering: 3 x 1 h at 560°C (1040°F).

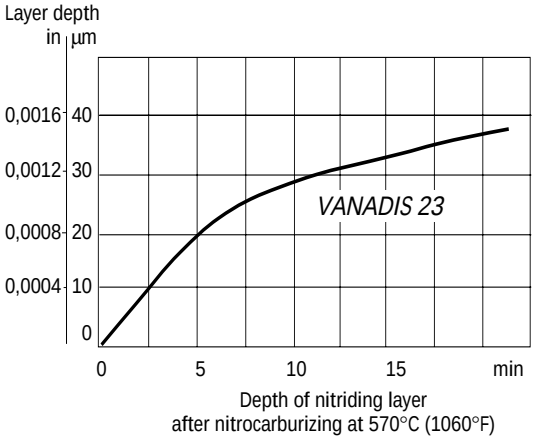


Surface treatments

The most commonly used treatments are nitriding and surface coating with wear resistant layers of titanium carbide and titanium nitride (CVD, PVD). *VANADIS 23* have been found to be particularly suitable for titanium carbide and titanium nitride coatings. The uniform carbide distribution in *VANADIS 23* facilitates bonding of the coating and reduces the spread of dimensional changes resulting from hardening. This, together with its high strength and toughness, makes *VANADIS 23* an ideal substrate for high-wear surface coatings.

NITRIDING

A brief immersion in a special salt bath to produce a nitrided diffusion zone of 2–20 µm is recommended.



PVD

Physical vapour deposition, PVD, is a method of applying a wear-resistant coating at temperatures between 200–500°C (390–930°F). As *VANADIS 23* is high temperature tempered at 560°C (1040°F) there is no danger of dimensional changes during PVD coating.

CVD

Chemical vapour deposition, CVD, is used for applying wear-resistant surface coatings at a temperature of around 1000°C (1830°F). It is recommended that the tools should be separately hardened and tempered in a vacuum furnace after surface treatment.

Cutting data recommendations

The cutting data below are to be considered as guiding values which must be adapted to existing local condition. More information can be found in the Uddeholm publication "Cutting data recommendations".

Condition: Soft annealed to approx. 260 HB

TURNING

Cutting data parameters	Turning with carbide		Turning with HSS
	Rough turning	Fine turning	Fine turning
Cutting speed (v_c) m/min f.p.m.	110–160 360–525	160–210 525–690	12–15 40–50
Feed (f) mm/r i.p.r.	0,2–0,4 0,008–0,016	0,05–0,2 0,002–0,008	0,05–0,3 0,002–0,012
Depth of cut (a_p) mm inch	2–4 0,08–0,16	0,5–2 0,02–0,08	0,5–3 0,02–0,12
Carbide designation ISO	K20* Coated carbide	K15* Coated carbide or cermet	–

** Use a wear resistant Al_2O_3-coated carbide*

DRILLING

High speed steel twist drill

Drill diameter		Cutting speed v_c		Feed f	
mm	inch	m/min.	f.p.m.	mm/r	i.p.r.
– 5	–3/16	10–12*	33–39*	0,05–0,10	0,002–0,004
5–10	3/16–3/8	10–12*	33–39*	0,10–0,20	0,004–0,008
10–15	3/8–5/8	10–12*	33–39*	0,20–0,25	0,008–0,012
15–20	5/8–3/4	10–12*	33–39*	0,25–0,30	0,012–0,014

** For coated HSS drill v_c = 16–18 m/min. (52–59 f.p.m.)*

Carbide drill

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Brazed carbide[1]
Cutting speed, v_c m/min f.p.m.	120–150 394–490	60–80 197–260	30–40 98–130
Feed, f mm/r i.p.r.	0,05–0,15[2] 0,002–0,006[2]	0,10–0,25[2] 0,004–0,01[2]	0,15–0,25[2] 0,006–0,01[2]

[1] Drill with internal cooling channels and brazed tip.
[2] Depending on drill diameter.

MILLING

Face and square shoulder milling

Cutting data parameters	Milling with carbide	
	Rough milling	Fine milling
Cutting speed (v_c) m/min f.p.m.	80–130 260–435	130–160 435–535
Feed (f_z) mm/tooth inch/tooth	0,2–0,4 0,008–0,016	0,1–0,2 0,004–0,008
Depth of cut (a_p) mm inch	2–4 0,08–0,16	–2 –0,08
Carbide designation ISO	K20* Coated carbide	K15* Coated carbide

** Use a wear resistant Al_2O_3-coated carbide*

End milling

Cutting data parameters	Type of mill		
	Solid carbide	Carbide indexable insert	High speed steel
Cutting speed (v_c) m/min f.p.m.	40–50 130–164	90–110 295–365	5–8[1] 16–26[1]
Feed (f_z) mm/tooth inch/tooth	0,01–0,2[2] 0,0004–0,008[2]	0,06–0,2[2] 0,002–0,008[2]	0,01–0,3[2] 0,0004–0,012[2]
Carbide designation ISO	–	K15[3]	–

[1] With coated HSS v_c = 12–16 m/min. (39–52 f.p.m.)
[2] Depending on radial depth of cut and cutter diameter.
[3] Use a wear resistant Al_2O_3-coated carbide.

GRINDING

General grinding wheel recommendation is given below. More information can be found in the Uddeholm publication "Grinding of Tool Steel".

Type of grinding	Annealed condition	Hardened condition
Face grinding straight wheel	A 46 HV	B151 R50 B3[1] A 46 HV
Face grinding segments	A 36 GV	A 46 GV
Cylindrical grinding	A 60 KV	B151 R50 B3[1] A 60 KV
Internal grinding	A 60 JV	B151 R75 B3[1] A 60 IV
Profile grinding	A 100 IV	B126 R100 B6[1] A 100 JV

[1] If possible use CBN wheels for this application.

Electrical-discharge machining

If EDM is performed in the hardened and tempered condition, finish with “fine-sparking”, i.e. low current, high frequency. For optimal performance the EDM’d surface should then be ground/polished and the tool retempered at approx. 535°C (995°F).

Relative comparison of Uddeholm PM steels

MATERIAL PROPERTIES AND RESISTANCE TO FAILURE MECHANISMS

Uddeholm grade	Hardness/ Resistance to plastic deformation	Machin-ability	Grind-ability	Dimension stability	Resistance to		Fatigue cracking resistance	
					Abrasive wear	Adhesive wear	Ductility/ resistance to chipping	Hot hardness
VANADIS 23								
VANADIS 30								
VANADIS 60								
AISI M:2								
AISI M35								

Further information

Please contact your local Uddeholm office for further information on the selection, heat treatment, application and availability of Uddeholm tool steels.