

VANADIS 4[®] Extra

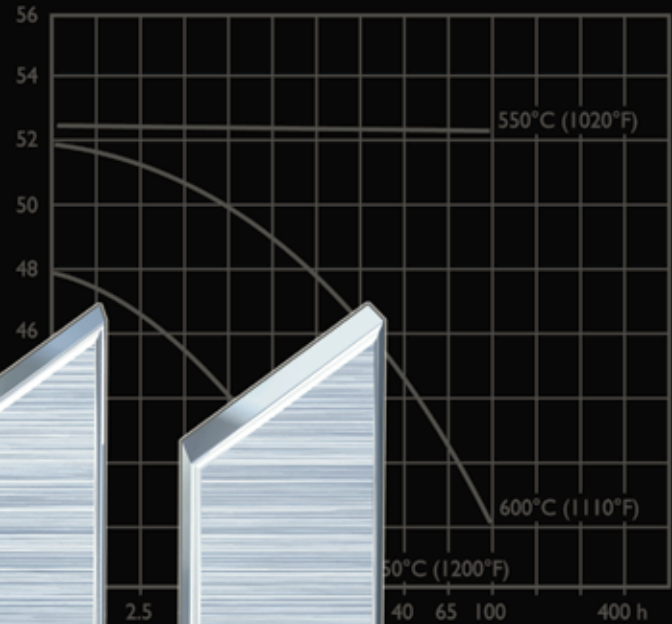
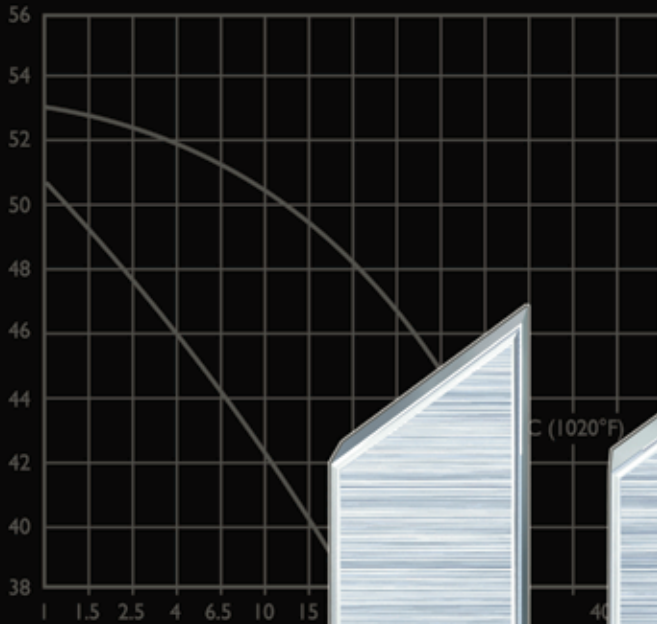
SUPERCLEAN³ Powder metallurgical cold work tool steel

COLD WORK

PLASTIC MOULDING

HOT WORK

HIGH PERFORMANCE STEEL



Typical analysis %	C 2,05	Cr 4,5	W 0,2
Standard specification	AISI D6, ()	()	()
Delivery condition	Soft annealed		to approx. 200 HB
Colour code	Red		

Temperature	20°C (68°F)	200°C (390°F)	400°C (750°F)
Density kg/m ³ lbs/m ³	7 770 0,281	7 770 0,281	7 650 0,275
Modulus of elasticity N/mm ² psi	194 000 28,1 × 10 ⁶	188 000 27,3 × 10 ⁶	173 000 25,1 × 10 ⁶
Coefficient of thermal expansion per °C from 20°C per °F from 68°F	to 100°C 11,7 × 10 ⁻⁶ to 212°F 6,5 × 10 ⁻⁶	to 200°C 12 × 10 ⁻⁶ to 400°F 6,7 × 10 ⁻⁶	to 400°C 13,0 × 10 ⁻⁶ to 750°F 7,3 × 10 ⁻⁶
Thermal conductivity W/m °C Btu in (ft ² h°F)	- -	27 187	32 221
Specific heat K/kg °C Btu/lbs °F	455 0,109	525 0,126	608 0,145

Critical tool steel parameters for

GOOD TOOL PERFORMANCE

- Correct hardness for the application
- High wear resistance
- High ductility

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

Vanadis 4 Extra is a powder metallurgical cold work tool steel offering an extremely good combination of wear resistance and ductility for high performance tools.

TOOLMAKING

- Machinability
- Heat treatment
- Dimensional stability during heat treatment

Toolmaking with highly alloyed tool steels has traditionally created problems with machining and heat treatment when compared with lower alloyed grades, this then often leads to increased toolmaking costs.

Due to our carefully balanced alloying and the powder metallurgical manufacturing process, Vanadis 4 Extra has better machinability than the tool steel grade AISI D2.

One major advantage with Vanadis 4 Extra is that the dimensional stability after hardening and tempering is much better than for all known high performance cold work tool steels. This means, for example, that Vanadis 4 Extra is a tool steel which is very suitable for surface treatments.

General

Vanadis 4 Extra is a chromium-molybdenum-vanadium alloyed steel which is characterized by:

- Very good ductility
- High abrasive-adhesive wear resistance
- High compressive strength
- Good dimensional stability during heat treatment and in service
- Very good through-hardening properties
- Good temper back resistance
- Good machinability and grindability

Typical analysis %	C	Si	Mn	Cr	Mo	V
	1.4	0.4	0.4	4.7	3.5	3.7
Delivery condition	Soft annealed to approx. 230 HB					
Color code	Green/white with black line across					

Applications

Vanadis 4 Extra is especially suitable for applications where adhesive wear and/or chipping are the dominating failure mechanisms, i.e.

- with soft/adherent materials such as austenitic stainless steel, mild steel, copper, aluminum, etc. as work material
- with thicker work material
- high strength work materials

Vanadis 4 Extra is however also very suitable for blanking and forming of Ultra High Strength Steel Sheet, these materials place high demands on the tool steel regarding abrasive wear resistance and ductility.

Examples:

- Blanking and forming
- Fine blanking
- Cold extrusion tooling
- Powder pressing
- Deep drawing
- Knives
- Substrate steel for surface coating

Properties

PHYSICAL DATA

Hardened and tempered to 60 HRC.

Temperature	(68°F) 20°C	(390°F) 200°C	(750°F) 400°C
Density lbs/in ³ kg/m ³	0,278 7 700	– –	– –
Modulus of elasticity psi N/mm ²	29.8 x 10 ⁶ 206 000	29.0 x 10 ⁶ 200 000	26.8 x 10 ⁶ 185 000
Coefficient of thermal expansion per °F from 68°F °C from 20°C	– –	6.0 x 10 ⁻⁶ 10.9 x 10 ⁻⁶	6.5 x 10 ⁻⁶ 11.7 x 10 ⁻⁶
Thermal conductivity Btu in/(ft ² h °F) W/m • °C	– –	210 30	210 30
Specific heat Btu/lb °F J/kg °C	0,11 460	– –	– –

This information is based on our present state of knowledge and is intended to provide general notes on our products and their uses. It should not therefore be construed as a warranty of specific properties of the products described or a warranty of fitness for a particular purpose.

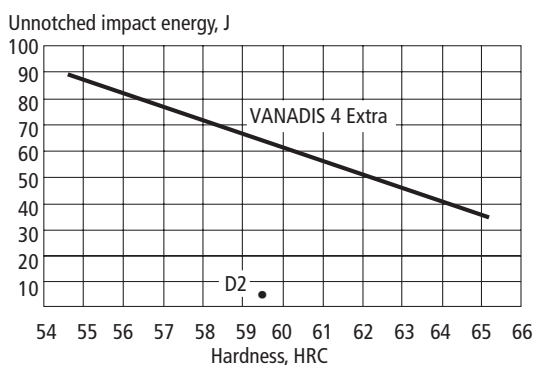
IMPACT STRENGTH

Approximate room temperature impact strength as a function of hardness is shown below.

Original bar dimension: Ø 4.133" (105 mm), samples are taken from the centre and tested in the transverse direction.

Specimen size: 0.27 x 0.40 x 2.2" (7 x 10 x 55 mm) unnotched. Hardened between 1725°F (940°C) and 2100°F (1150°C). Holding time 30 minutes up to 1100°C, over 1100°C 15 minutes. Quenched in air. Tempered 2 x 2h between 980°F (525°C) and 1060°F (570°C).

The difference in ductility between Vanadis 4 Extra and AISI D2 at different hardness levels



Heat treatment

SOFT ANNEALING

Protect the steel and heat through to 1650°F (900°C). Cool in the furnace at 20°F (10°C) per hour to 1380°F (750°C), then freely in air.

STRESS RELIEVING

After rough machining the tool should be heated through to 1200°F (650°C), holding time 2 hours. Cool slowly to 930°F (500°C), then freely in air.

HARDENING

Pre-heating temperature: 1110–1290°F (600–700°C).

Austenitizing temperature: 1725–2100°F (940–1150°C). Normally 1870°F (1020°C). For large sections >2.75" (70 mm) use 1940°F (1060°C).

Holding time: 30 min. up to 2010°F (1100°C), 15 min. above 2010°F (1100°C).

N.B. Holding time = time at hardening temperature after the tool is fully heated through. A holding time of less than recommended above will result in loss of hardness.

Protect the part against decarburization and oxidation during hardening.

QUENCHING MEDIA

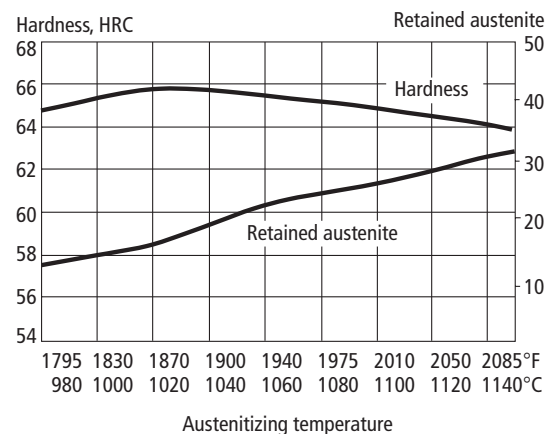
- Vacuum (high speed gas at sufficient over-pressure)
- Martempering bath or fluidized bed at 930–1020°F (500–550°C)
- Martempering bath or fluidized bed at 390–660°F (200–350°C).

Note 1: Temper the tool as soon as its temperature reaches 120–160°F (50–70°C).

Note 2: In order to obtain the optimum properties for the tool, the cooling rate should be as fast as is concomitant with acceptable distortion.

Note 3: Martempering should be followed by forced air cooling if wall thickness is exceeding 2.75" (70 mm).

Hardness and retained austenite as a function of austenitizing temperature



TEMPERING

The tempering temperature can be selected according to the hardness required by reference to the tempering graph below.

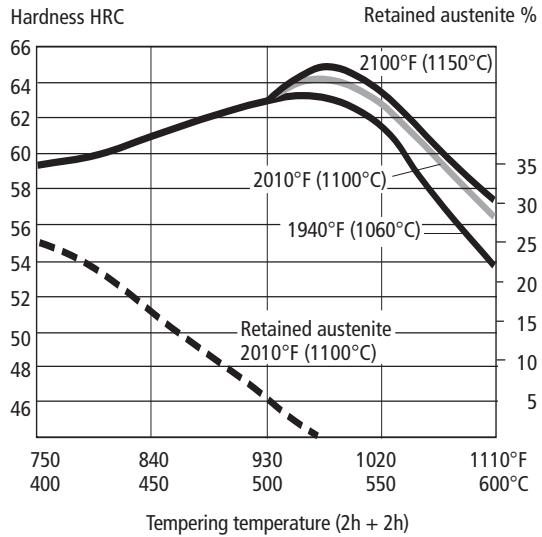
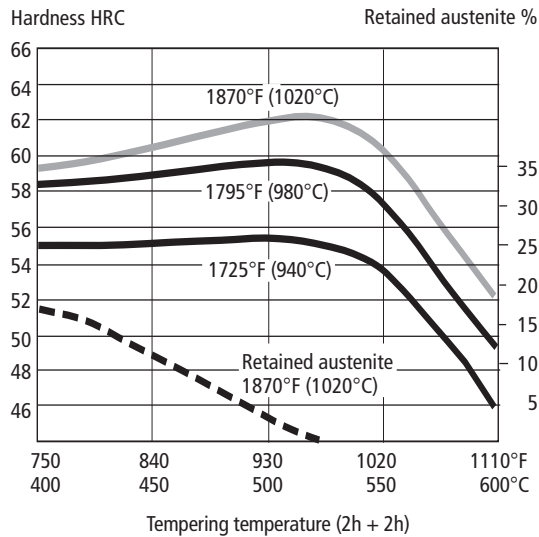
Temper twice with intermediate cooling to room temperature. The lowest tempering temperature

which should be used is 980°F (525°C). The minimum holding time at temperature is 2 hours.

In order not to reduce the toughness do not temper below 980°F (525°C)

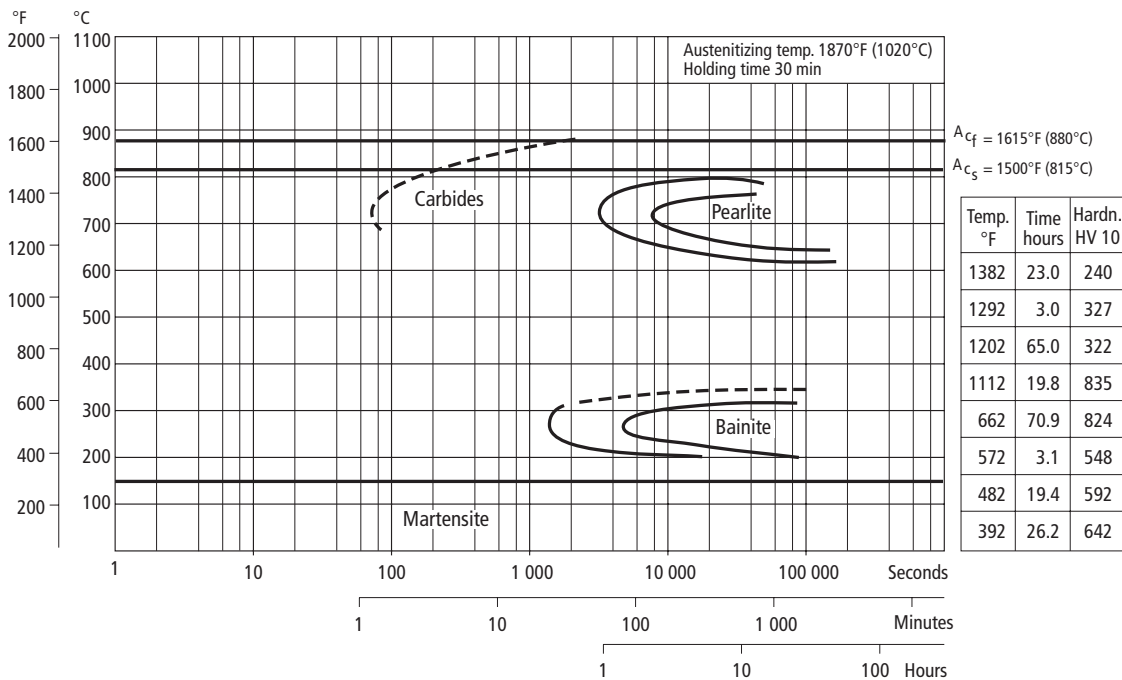
To avoid a high content of retained austenite choose tempering temperature over 980°F (525°C).

Tempering graph



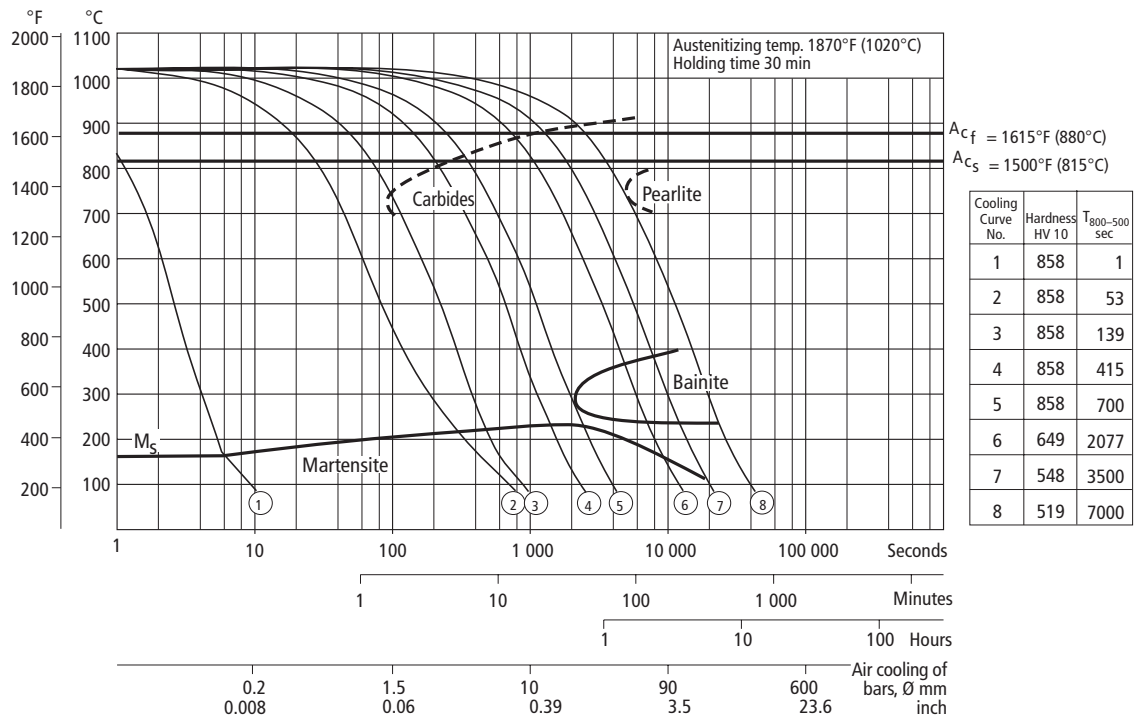
TTT-graph

Austenitizing temperature 1870°F (1020°C). Holding time 30 minutes.



CCT-graph

Austenitizing temperature 1870°F (1020°C). Holding time 30 minutes.



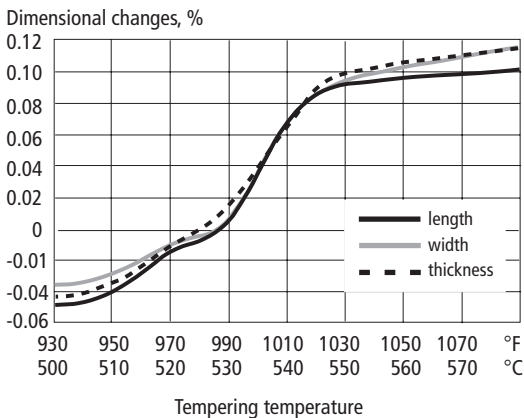
DIMENSIONAL CHANGES DURING HARDENING AND TEMPERING

Dimensional changes have been measured after hardening and tempering.

Austenitizing: 1870°F/30 min. (1020°C/30 min.), cooling in vacuum furnace at 2°F/sec (1,1°C/sec) between 1470°F (800°C) and 930°F (500°C).

Tempering: 2 x 2 h at various temperatures
Sample size: 3.15" x 3.15" x 3.15" (80 x 80 x 80 mm)

Dimensional changes during hardening and tempering in length, width and thickness direction



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 -95 to -110°F (-70 and -80°C), soaking time 3-4 hours, followed by tempering.

The tempering temperature should be lowered 50°F (25°C) in order to get the desired hardness when a high temperature temper is performed.

Avoid intricate shapes as there will be risk of cracking.

Surface treatment

Some cold work tool steels are given a surface treatment in order to reduce friction and increase wear resistance. The most commonly used treatments are nitriding and surface coating with wear resistant layers produced via PVD and CVD.

The high hardness and toughness together with a good dimensional stability makes Vanadis 4 Extra ideal as a substrate steel for various surface coatings.

NITRIDING

Nitriding gives a hard surface layer that is resistant to wear and erosion.

Vanadis 4 Extra is normally high temperature tempered at around 980°F (525°C). This means that the nitriding temperature used should not exceed 930–980°F (500–525°C). Ion nitriding at a temperature below the tempering temperature used is preferred. The surface hardness after nitriding is approximately 1150 HV_{0,2 kg}.

The thickness of the layer should be chosen to suit the application in question.

PVD

Physical vapor deposition, PVD, is a method of applying a wear resistant coating at temperatures between 390–930°F (200–500°C).

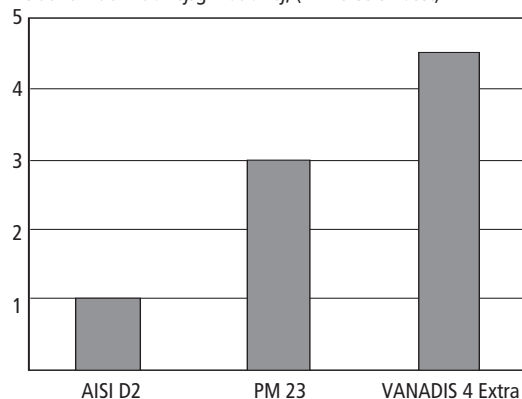
CVD

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

Machinability

Relative machinability and grindability for AISI D2, PM 23 and Vanadis 4 Extra. High value indicates good machinability/grindability.

Relative machinability/grindability, (1=worse 5=best)



Machining recommendations

The cutting data below are to be considered as guiding values which must be adapted to existing local conditions.

Delivery condition: Soft annealed to ~230 HB

TURNING

Cutting data parameters	Turning with carbide		Turning with HSS Fine turning
	Rough turning	Fine turning	
Cutting speed (v_c) f.p.m. m/min.	395–560 120–170	560–720 170–220	50–65 15–20
Feed (f) i.p.r. mm/rev	0.008–0.016 0.2–0.4	0.002–0.008 0.05–0.2	0.002–0.012 0.05–0.3
Depth of cut (a_p) inch mm	0.08–0.16 2–4	0.02–0.08 0,5–2	0.02–0.08 0,5–3
Carbide designation ISO	K20*, P20*	K15*, P15*	–

* Use a wear resistant CVD-coated carbide grade

DRILLING

High speed steel twist drill

Drill diameter		Cutting speed (v_c)		Feed (f)	
inch	mm	f.p.m.	m/min	i.p.r.	mm/rev
–3/16	–5	40–46*	12–14*	0.002–0.006	0.05–0.15
3/16–3/8	5–10	40–46*	12–14*	0.006–0.010	0.15–0.25
3/8–5/8	10–15	40–46*	12–14*	0.010–0.012	0.25–0.30
5/8–3/4	15–20	40–46*	12–14*	0.012–0.014	0.30–0.35

* For coated HSS drills $v_c = 72–80$ f.p.m. (22–24 m/min.).

Carbide drill

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Brazed carbide ¹⁾
Cutting speed (v_c) f.p.m. m/min.	460–525 140–160	260–330 80–100	165–200 50–60
Feed (f) i.p.r. mm/rev	0.002–0.006 ²⁾ 0.05–0.15 ²⁾	0.004–0.010 ²⁾ 0.10–0.25 ²⁾	0.006–0.01 ²⁾ 0.15–0.25 ²⁾

¹⁾ Drills with internal cooling channels and a 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) f.p.m. m/min.	360–490 110–150	490–655 150–200
Feed (f_z) in/tooth mm/tooth	0.008–0.016 0.2–0.4	0.004–0.008 0.1–0.2
Depth of cut (a_p) inch mm	0.08–0.16 2–4	– 0.08 – 2
Carbide designation ISO	K20, P20 coated carbide [*]	K15, P15 coated carbide [*]

^{*} Use a wear resistant CVD coated carbide grade

End milling

Cutting data parameters	Type of milling		
	Solid carbide	Carbide indexable insert	High speed steel ¹⁾
Cutting speed (v_c) f.p.m. m/min.	200–260 60–80	360–525 110–160	26–40 8–12
Feed (f_z) in/tooth mm/tooth	0.001–0.008 ²⁾ 0.03–0.20 ²⁾	0.003–0.008 ²⁾ 0.08–0.20 ²⁾	0.002–0.014 ²⁾ 0.05–0.35 ²⁾
Carbide designation ISO	–	K15 ³⁾	–

¹⁾ For coated HSS end mill $v_c = 60–80$ f.p.m. (18–24 m/min.)

²⁾ Depending on radial depth of cut and cutter diameter

³⁾ Use a wear resistant CVD coated carbide grade

GRINDING

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

Wheel recommendation

Type of grinding	Soft annealed condition	Hardened condition
Face grinding straight wheel	A 46 HV	B151 R50 B3 ¹⁾ A 46 HV ²⁾
Face grinding segments	A 24 GV	A46 FV A46 FV ²⁾
Cylindrical grinding	A 60 KV	B151 R75 B3 ¹⁾ A 60 KV ²⁾
Internal grinding	A 60 JV	B151 R75 B3 ¹⁾ A 60 KV ²⁾
Profile grinding	A 100 LV	B126 R100 B6 ¹⁾ A 80 JV ²⁾

¹⁾ If possible use CBN wheels for this application

²⁾ Grinding wheels containing abrasive of sintered type is recommended

Electrical-discharge machining —EDM

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. 45°F (25°C) lower than the original tempering temperature.

When EDM'ing larger sizes or complicated shapes Vanadis 4 Extra should be tempered at high temperatures, above 930°F (500°C).

Relative comparison of Uddeholm cold work tool steel

MATERIAL PROPERTIES AND RESISTANCE TO FAILURE MECHANISMS

Uddeholm grade	Hardness/ Resistance to plastic deformation	Machinability	Grindability	Dimension stability	Resistance to		Fatigue cracking resistance	
					Abrasive wear	Adhesive wear	Ductility/ resistance to chipping	Toughness/ gross cracking
COMPAX SUPREME	████	████████	████████	████	██	████	████████	████
AISI D2	████	██████	██	████	██████	██	██	████
VANADIS 4 Extra	████████	██████	████	████████	██████	██████	██████	████
VANADIS 6	██████	██	██	██████	██████	██████	██████	██
VANADIS 10	██████	██	██	██████	██████	██████	██████	██
VANADIS 30	██████	██	██	██████	██████	██████	██████	██
VANADIS 60	██████	██	██	██████	██████	██████	██████	██
AISI M:2	████	████	██	████	████	██	██	██

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