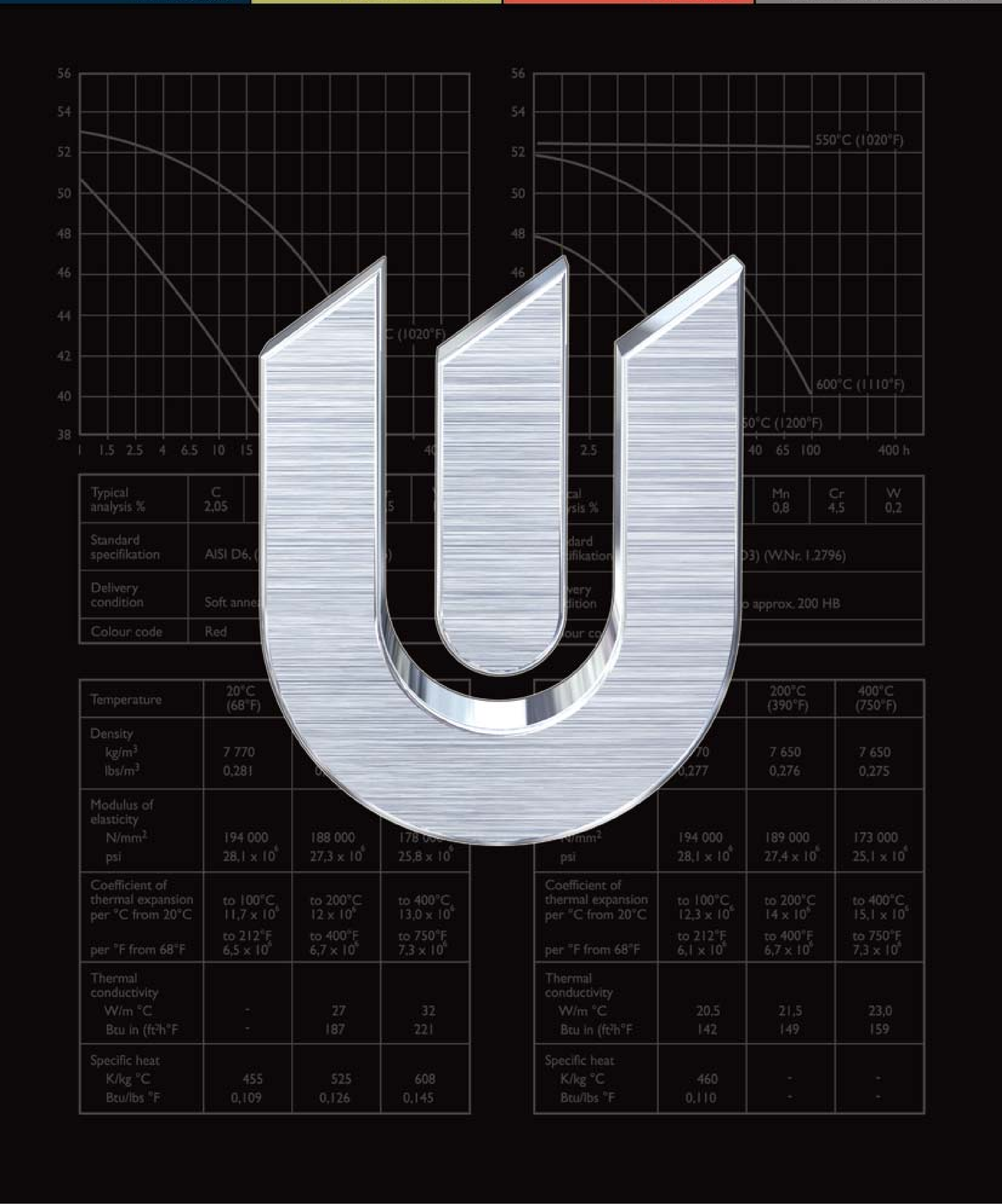
VANADIS 4 Extra

SUPERCLEAN[3]

Powder metallurgical cold work tool steel

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



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 CVD coating.

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 1,4	Si 0,4	Mn 0,4	Cr 4,7	Mo 3,5	V 3,7
Delivery condition	Soft annealed to approx. 230 HB					
Colour code	Green/white with a 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, aluminium, 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.

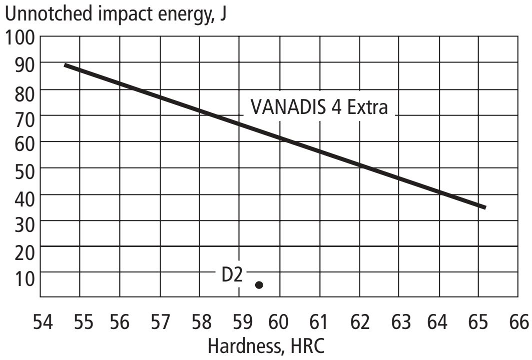
Temperature	20°C (68°F)	200°C (390°F)	400°C (750°F)
Density kg/m³ lbs/in³	 7 700 0,278	 – –	 – –
Modulus of elasticity N/mm² psi	 206 000 29,8 x 10^6	 200 000 29,0 x 10^6	 185 000 26,8 x 10^6
Coefficient of thermal expansion per °C from 20°C °F from 68°F	 – –	 10,9 x 10^{-6} 6,0 x 10^{-6}	 11,7 x 10^{-6} 6,5 x 10^{-6}
Thermal conductivity W/m • °C Btu in/(ft² h °F)	 – –	 30 210	 30 210
Specific heat J/kg °C Btu/lb °F	 460 0,11	 – –	 – –

IMPACT STRENGTH

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

Original bar dimension: Ø 105 mm, samples are taken from the centre and tested in the transverse direction.
Specimen size: 7 x 10 x 55 mm (0,27 x 0,40 x 2,2") unnotched. Hardened between 940°C (1725°F) and 1150°C (2100°F) for 30 minutes, over 1100°C (2010°F) for 15 minutes. Quenched in air. Tempered 2 x 2h between 525°C (980°F) and 570°C (1060°F).

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

STRESS RELIEVING

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

HARDENING

Pre-heating temperature: 600–700°C (1110–1290°F).
Austenitizing temperature: 940–1150°C (1725–2100°F). Normally 1020°C (1870°F). For large sections >70 mm (2,75") use 1060°C (1940°F).
Holding time: 30 min. up to 1100°C (2010°F), 15 min. above 1100°C (2010°F).

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

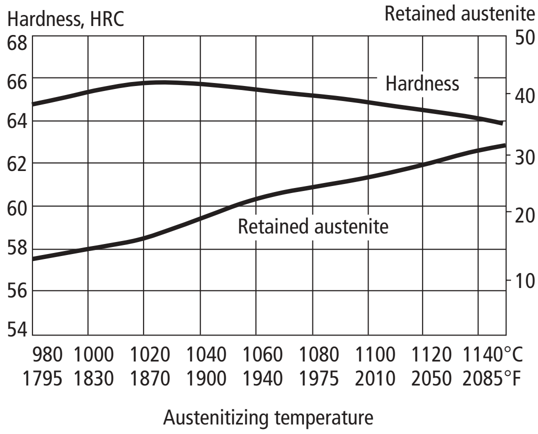
- Vacuum (high speed gas at sufficient over-pressure)
- Martempering bath or fluidized bed at 500–550°C (930–1020°F)
- Martempering bath or fluidized bed at 200–350°C (390–660°F).

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

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 70 mm (2,75").

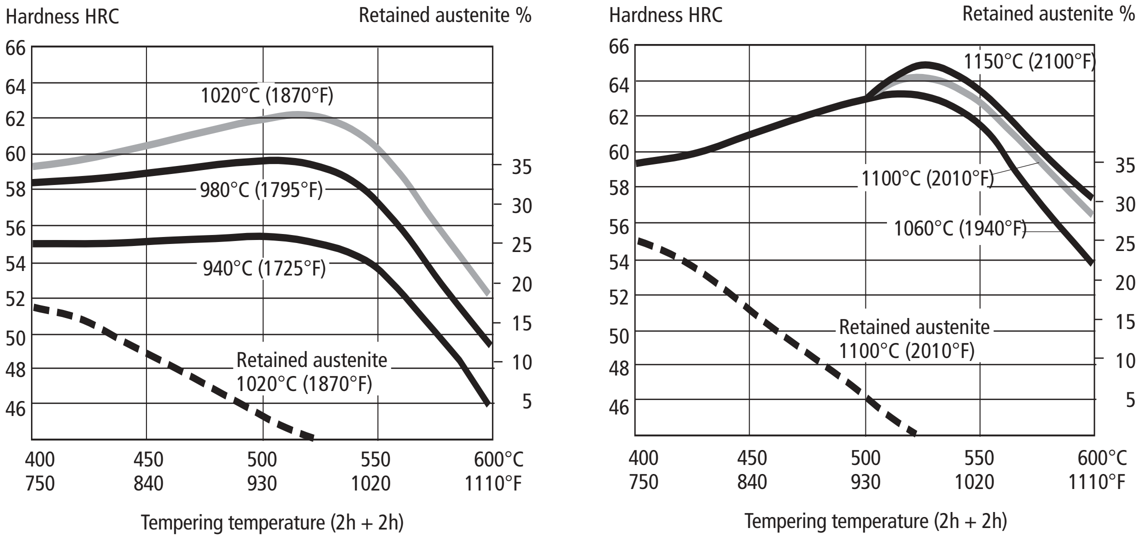
Hardness and retained austenite as a function of austenitizing temperature



TEMPERING

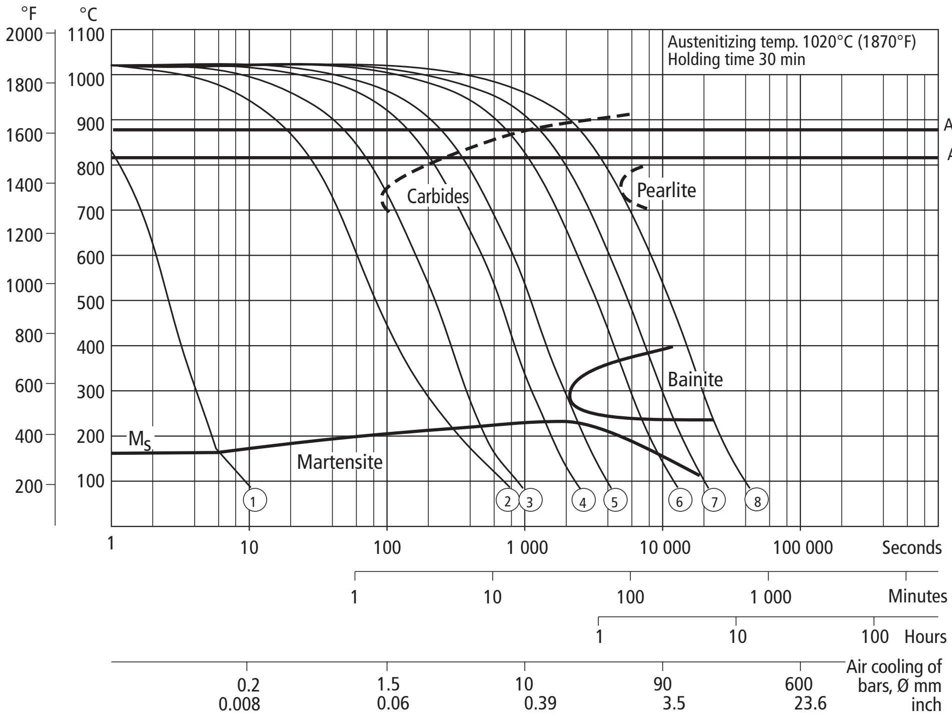
The tempering temperature can be selected according to the hardness required by reference to the tempering graph below.
Temper twice with intermediate cooling to room temperature. The lowest tempering temperature which should be used is 525°C (980°F). The minimum holding time at temperature is 2 hours.
In order not to reduce the toughness do not temper below 525°C (980°F)
To avoid a high content of retained austenite choose tempering temperature over 525°C (980°F).

Tempering graph



CCT-graph

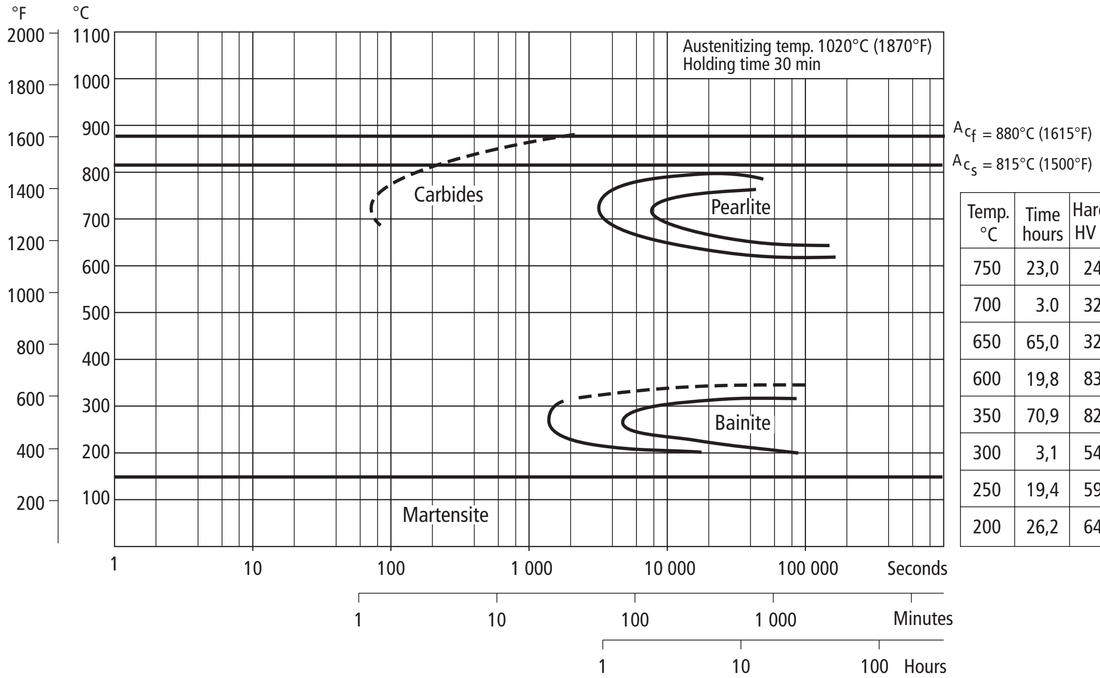
Austenitizing temperature 1020°C (1870°F). Holding time 30 minutes.



Cooling Curve No.	Hardness HV 10	$T_{800-500}$ sec
1	858	1
2	858	53
3	858	139
4	858	415
5	858	700
6	649	2077
7	548	3500
8	519	7000

TTT-graph

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



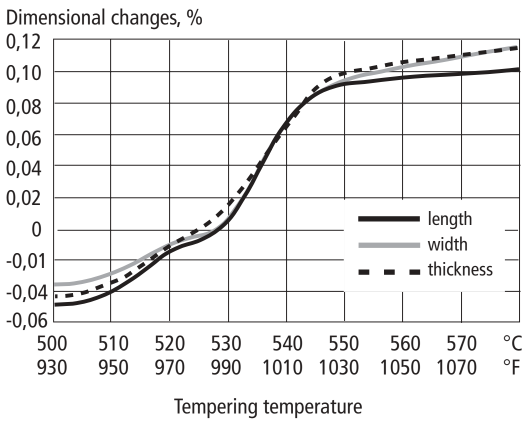
Temp. °C	Time hours	Hardn. HV 10
750	23,0	240
700	3.0	327
650	65,0	322
600	19,8	835
350	70,9	824
300	3,1	548
250	19,4	592
200	26,2	642

DIMENSIONAL CHANGES DURING HARDENING AND TEMPERING

Dimensional changes have been measured after hardening and tempering.

Austenitizing: 1020°C/30 min. (1870°F/30 min.), cooling in vacuum furnace at 1,1°C/sec (2°F/sec) between 800°C (1470°F) and 500°C (930°F).
Tempering: 2 x 2 h at various temperatures
Sample size: 80 x 80 x 80 mm (3,15" x 3,15" x 3,15")

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 –70 and –80°C (–95 to –110°F), soaking time 3–4 hours, followed by tempering.
The tempering temperature should be lowered 25°C (50°F) 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 525°C (980°F) This means that the nitriding temperature used should not exceed 500–525°C (930–980°F). 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 vapour deposition, PVD, is a method of applying a wear resistant coating at temperatures between 200–500°C (390–930°F).

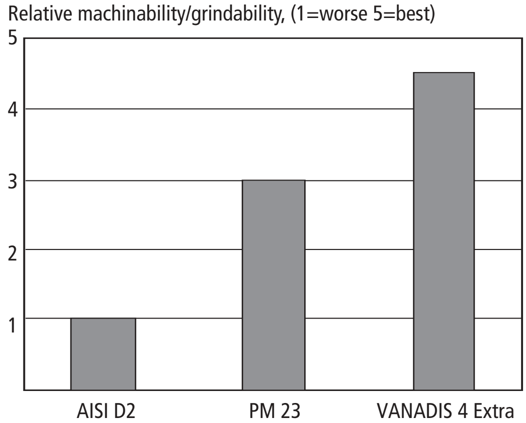
CVD

Chemical vapor 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.

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 Rough turning	Turning with carbide Fine turning	Turning with HSS Fine turning
Cutting speed (v_c) m/min. f.p.m.	120–170 395–560	170–220 560–720	15–20 50–65
Feed (f) mm/rev 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 0,02–0,08
Carbide designation ISO	K20*, P20*	K15*, P15*	–

** Use a wear resistant CVD-coated carbide grade*

MILLING

Face and square shoulder milling

Cutting data parameters	Milling with carbide Rough milling	Milling with carbide Fine milling
Cutting speed (v_c) m/min. f.p.m.	110–150 360–490	150–200 490–655
Feed (f_z) mm/tooth in/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, 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) m/min. f.p.m.	60–80 200–260	110–160 360–525	8–12 26–40
Feed (f_z) mm/tooth in/tooth	0,03–0,20[2)] 0,001–0,008[2)]	0,08–0,20[2)] 0,003–0,008[2)]	0,05–0,35[2)] 0,002–0,014[2)]
Carbide designation ISO	–	K15[3)]	–

1) For coated HSS end mill v_c = 18–24 m/min. (60–80 f.p.m.)
2) Depending on radial depth of cut and cutter diameter
3) Use a wear resistant CVD coated carbide grade

DRILLING

High speed steel twist drill

Drill diameter		Cutting speed (v_c)		Feed (f)	
mm	inch	m/min	f.p.m.	mm/rev	i.p.r.
–5	–3/16	12–14*	40–46*	0,05–0,15	0,002–0,006
5–10	3/16–3/8	12–14*	40–46*	0,15–0,25	0,006–0,010
10–15	3/8 –5/8	12–14*	40–46*	0,25–0,30	0,010–0,012
15–20	5/8 –3/4	12–14*	40–46*	0,30–0,35	0,012–0,014

** For coated HSS drills v_c = 22–24 m/min. (72–80 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.	140–160 460–525	80–100 260–330	50–60 165–200
Feed (f) mm/rev i.p.r.	0,05–0,15[2)] 0,002–0,006[2)]	0,10–0,25[2)] 0,004–0,010[2)]	0,15–0,25[2)] 0,006–0,01[2)]

1) Drills with internal cooling channels and a brazed tip.
2) Depending on drill diameter.

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 recommeded

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. 25°C (45°F) lower than the original tempering temperature. When EDM'ing larger sizes or complicated shapes Vanadis 4 Extra should be tempered at high temperatures, above 500°C (930°F).

Relative comparison of Uddeholm cold work tool steel

MATERIAL PROPERTIES AND RESISTANCE TO FAILURE MECHANISMS