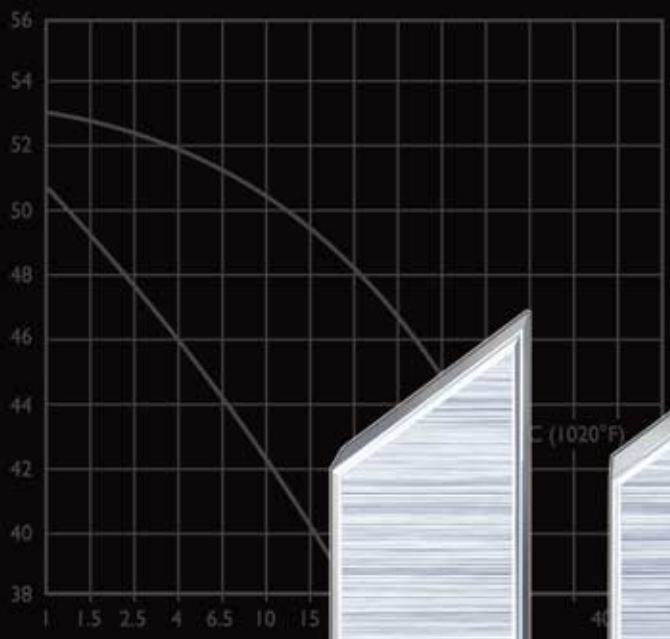
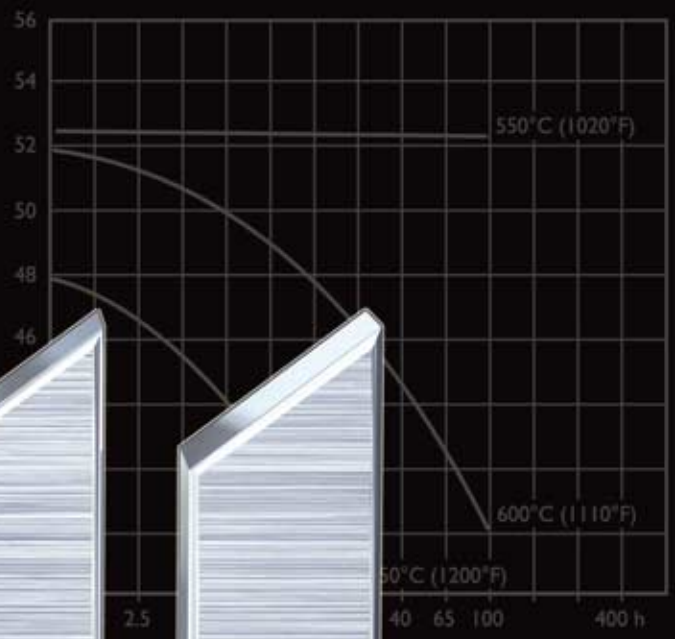
VANADIS 4–SuperClean™

High performance powder metallurgical cold work tool steel

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,						
Delivery condition	Soft anne						
Colour code	Red						

Temperature	20°C (68°F)	200°C (390°F)	400°C (750°F)
Density kg/m³	7 770	7 650	7 650
Density lbs/in³	0,281	0,276	0,275
Modulus of elasticity N/mm²	194 000	188 000	
Modulus of elasticity psi	28,1 x 10⁶	27,3 x 10⁶	25,8 x 10⁶
Coefficient of thermal expansion per °C from 20°C	to 100°C 11,7 x 10⁻⁶	to 200°C 12 x 10⁻⁶	to 400°C 13,0 x 10⁻⁶
Coefficient of thermal expansion per °F from 68°F	to 212°F 6,5 x 10⁻⁶	to 400°F 6,7 x 10⁻⁶	to 750°F 7,3 x 10⁻⁶
Thermal conductivity W/m °C	-	27	32
Thermal conductivity Btu in (ft²h°F	-	187	221
Specific heat K/kg °C	455	525	608
Specific heat Btu/lbs °F	0,109	0,126	0,145

Temperature	200°C (390°F)	400°C (750°F)
Density kg/m³	7 650	7 650
Density lbs/in³	0,276	0,275
Modulus of elasticity psi	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	to 100°C 12,3 x 10⁻⁶	to 200°C 14 x 10⁻⁶	to 400°C 15,1 x 10⁻⁶
Coefficient of thermal expansion per °F from 68°F	to 212°F 6,1 x 10⁻⁶	to 400°F 6,7 x 10⁻⁶	to 750°F 7,3 x 10⁻⁶
Thermal conductivity W/m °C	20,5	21,5	23,0
Thermal conductivity Btu in (ft²h°F	142	149	159
Specific heat K/kg °C	460	-	-
Specific heat Btu/lbs °F	0,110	-	-

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, for optimal tool performance both high wear resistance and ductility are essential in many cases.

VANADIS 4 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 on heat treatment
- Surface treatment.

Toolmaking with highly alloyed tool steels means that machining and heat treatment are often more of a problem than with the lower alloyed grades. This can, of course, raise the cost of toolmaking.

Due to the very carefully balanced alloying and the powder metallurgical manufacturing route, *VANADIS 4* has a similar machinability and heat treatment procedure to the tool steel grade AISI D2. One very big advantage with *VANADIS 4* 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* is a tool steel which is very suitable for CVD coating.

Applications

VANADIS 4 is especially suitable for applications where adhesive wear and/or chipping are the dominating problems, i.e.

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

Examples:

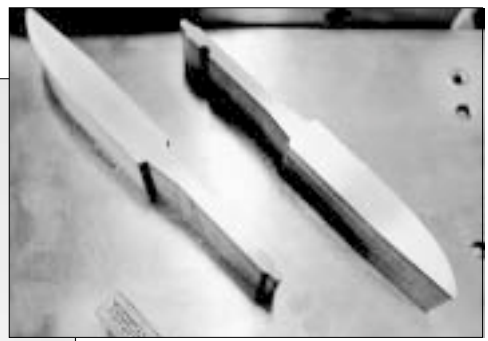
- Blanking and forming
- Fine blanking
- Cold extrusion tooling
- Powder pressing
- Deep drawing
- Knives.

General

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

- High wear resistance
- High compressive strength
- Very good through-hardening properties
- Very good ductility
- Excellent dimensional stability after hardening and tempering
- Good resistance to tempering back.

Typical analysis %	C 1,5	Si 1,0	Mn 0,4	Cr 8,0	Mo 1,5	V 4,0
Delivery condition	Soft annealed to approx. 235 HB					
Colour code	Green/white					



Properties

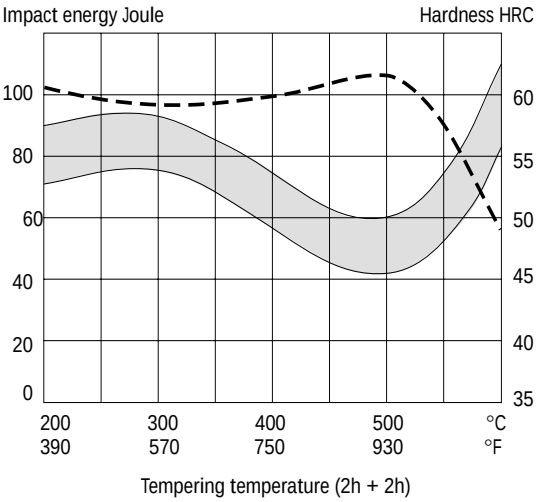
PHYSICAL DATA

Hardened and tempered to 60 HRC.

Temperature	20°C (68°F)	200°C (390°F)	400°C (750°F)
Density kg/m^3 lbs/in^3	 7 600 0,273	 – –	 – –
Modulus of elasticity N/mm^2 psi	 225 000 32,6 x 10^6	 208 000 30,1 x 10^6	 190 000 27,5 x 10^6
Coefficient of thermal expansion per °C from 20°C °F from 68°F	 – –	 10,8 x 10^{-6} 6,0 x 10^{-6}	 11,9 x 10^{-6} 6,6 x 10^{-6}
Thermal conductivity W/m • °C Btu in/(ft^2 h °F)	 15 104	 18 125	 21 147
Specific heat J/kg °C Btu/lb °F	 460 0,11	 – –	 – –

IMPACT STRENGTH

Approximate room temperature impact strength at different tempering temperatures.
Specimen size: 7 x 10 x 55 mm (0,27 x 0,40 x 2,2") unnochted. Hardened at 1020°C (1870°F). Quenched in air. Tempered twice.



Fine blanking puts very high demands on wear resistance and ductility, especially when the work material is thick. Excellent results have been obtained with this VANADIS 4 tool used for fine blanking 5 mm (0,2") thick material.

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: 980–1100°C (1800–2010°F). Normally 1020°C (1870°F). For large sections >70 mm (2,75") use 1060°C (1940°F).
Holding time: 30 min.

N.B. Holding time = time at hardening temperature after the tool is fully heated through. A holding time of less than 30 minutes will result in loss of hardness.

Protect the part against decarburization and oxidation during hardening.

QUENCHING MEDIA

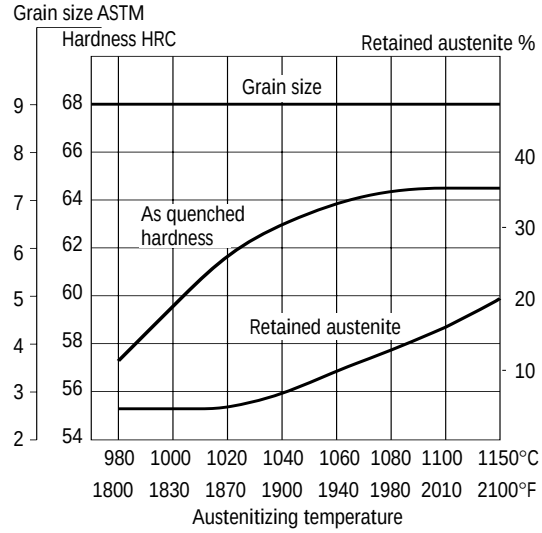
- Vacuum (high speed gas at sufficient over-pressure)
- Martempering bath or fluidized bed at 500–550°C (930–1020°F)
- Martempering bath or fluidized bed at 200–350°C (390–660°F).

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").

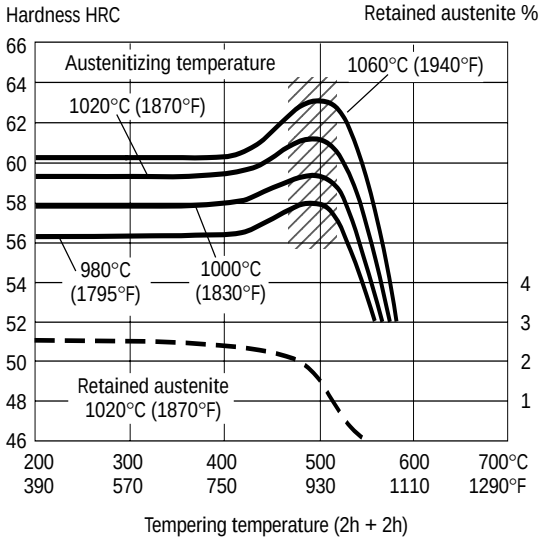
Hardness, grain size and retained austenite as functions of austenitizing temperature.

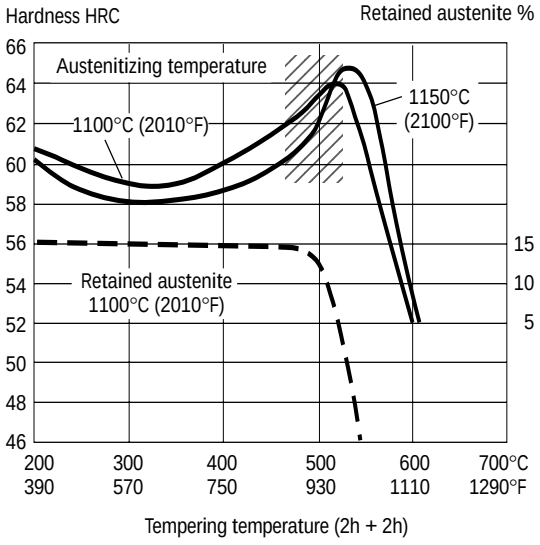


TEMPERING

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 180°C (360°F). The minimum holding time at temperature is 2 hours.
In order not to reduce the toughness do not temper in the range 470–520°C (880–970°F).

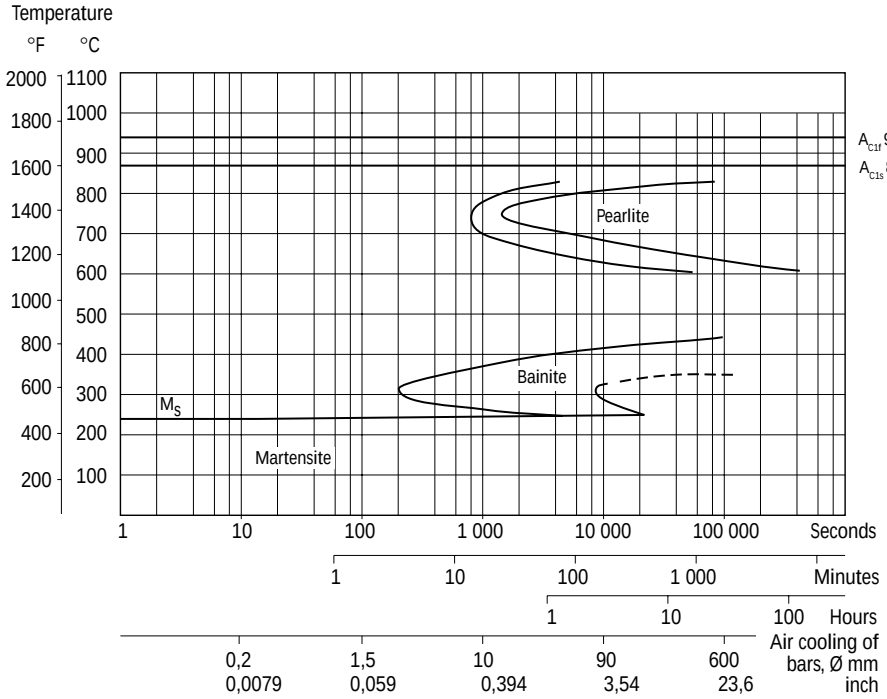
Tempering graph





TTT-graph

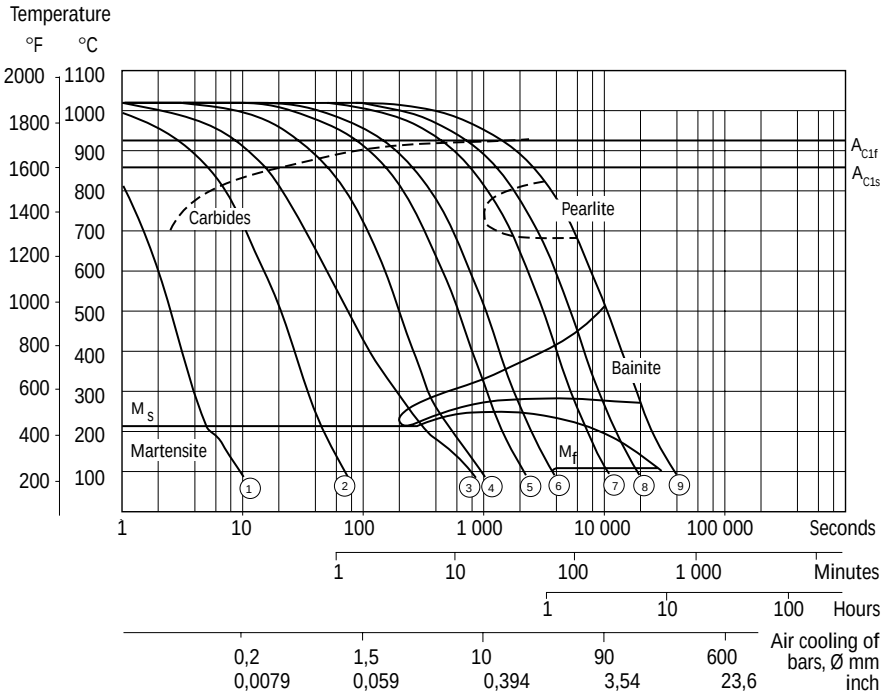
Austenitizing temperature 1020°C (1870°F). Holding time 30 minutes.



Temp. °C.	Time hours	Hardness HV10
825	4,6	530
800	18,2	222
750	1,0	270
700	1,8	213
650	47,1	342
600	70,3	370
450	19,3	803
400	25,9	772
350	18,0	792
300	2,6	634
250	5,3	606

CCT-graph

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

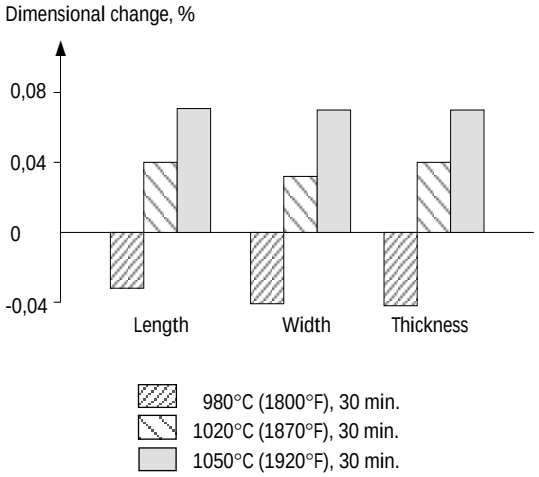


Cooling curve No.	Hardness HV 10	$T_{800-500}$ (sec)
1	835	1
2	835	14
3	824	42
4	782	139
5	782	415
6	724	700
7	620	2077
8	483	3500
9	274	7000

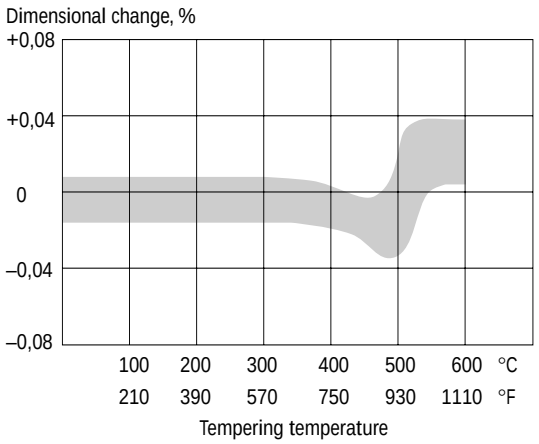
DIMENSIONAL CHANGES DURING HARDENING

Sample plate 100 x 100 x 25 mm (4" x 4" x 1").

Sample cube 80 x 80 x 80 mm
(3 1/8" x 3 1/8" x 1/8").



DIMENSIONAL CHANGES DURING TEMPERING



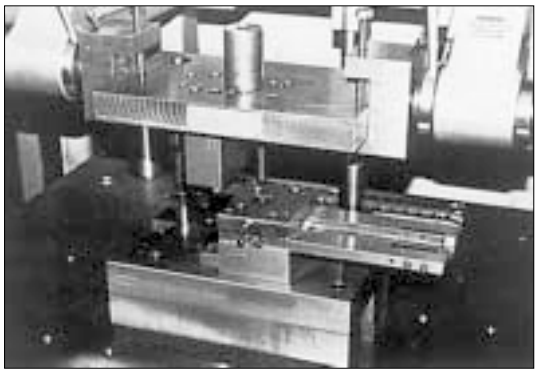
Note: The dimensional changes on hardening and tempering should be added together.

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. Sub-zero treatment will give a hardness increase of ~1 HRC. Avoid intricate shapes as there will be risk of cracking.

NITRIDING

Nitriding gives a hard surface layer that is resistant to wear and erosion.
VANADIS 4 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 1250 $HV_{0,2\ kg}$. The thickness of the layer should be chosen to suit the application in question.



Blanking tool made from VANADIS 4 for blanking of 10 mm (0,4") thick plate.

Machining recommendations

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

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.	70–100	100–150	15
f.p.m.	230–320	320–490	50
Feed (f) mm/rev	0,3–0,6	– 0,3	–0,3
i.p.r.	0,01–0,024	– 0,01	– 0,01
Depth of cut (a_p) mm	2–6	– 2	– 2
inch	0,08–0,24	– 0,08	– 0,08
Machining group ISO	K15*	K15*	–

** Use a wear resistant Al_2O_3-coated carbide grade, e.g. Sandvik Coromant GC 3015 or SECO TP05.*

DRILLING

High speed steel twist drill

Drill diameter mm	Drill diameter inch	Cutting speed (v_c) m/min	Cutting speed (v_c) f.p.m.	Feed (f) mm/rev	Feed (f) i.p.r.
–5	–3/16	10*	33*	0,08–0,20	0,003–0,008
5–10	3/16–3/8	10*	33*	0,20–0,30	0,008–0,012
10–15	3/8 –5/8	10*	33*	0,30–0,35	0,012–0,014
15–20	5/8 –3/4	10*	33*	0,35–0,40	0,014–0,016

** For coated HSS drills v_c ~14 m/min. (45 f.p.m.).*

Carbide drill

Cutting data parameters	Type of drill: Indexable insert	Type of drill: Solid carbide	Type of drill: Brazed carbide[1)]
Cutting speed (v_c) m/min.	100–150	45	30
f.p.m.	330–490	145	100
Feed (f) mm/rev	0,05–0,25[2)]	0,10–0,25[2)]	0,15–0,25[2)]

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

MILLING

Face and square shoulder milling

Cutting data parameters	Milling with carbide Rough milling	Milling with carbide Fine milling	Milling with HSS Fine milling
Cutting speed (v_c) m/min.	50–90	90–110	10
f.p.m.	160–295	295–360	33
Feed (f_z) mm/tooth	0,2–0,4	0,1–0,2	0,1
in/tooth	0,008–0,016	0,004–0,008	0,004
Depth of cut (a_p) mm	2–5	– 2	– 2
inch	0,08–0,20	– 0,08	– 0,08
Carbide designation ISO	K15*	K15*–	

**Use a wear resistant Al_2O_3-coated carbide grade, e.g. Sandvik Coromant GC 3015 or SECO T10M*

End milling

Cutting data parameters	Type of milling: Solid carbide	Type of milling: Carbide indexable insert	Type of milling: High speed steel
Cutting speed (v_c) m/min.	25	60–100	10[1)]
f.p.m.	80	195–330	33[1)]
Feed (f_z) mm/tooth	0,03–0,2[2)]	0,08–0,2[2)]	0,05–0,35[2)]
in/tooth	0,001–0,008[2)]	0,003–0,008[2)]	0,002–0,014[2)]
Carbide designation ISO	K20	K15[3)]	–

[1)] For coated HSS end mill v_c ≈14m/min. (45 f.p.m.)
[2)] depending on radial depth of cut and cutter diameter
[3)] Use a wear resistant Al_2O_3-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	B107 R75 B3[1)] 3SG 46 GVS[2)] C46 GV
Face grinding segments	A 24 GV	3SG 46 FVSPF[2)] A46 FV
Cylindrical grinding	A 60 JV	B126 R75 B3[1)] 5SG 70 IVS[2)] C60 IV
Internal grinding	A 46 JV	B107 R75 B3[1)] 3SG 60 JVS[2)] C60 HV
Profile grinding	A 100 LV	B107 R100V[1)] 5SG 80 JVS[2)] C120 HV

[1)] If possible use CBN wheels for this application.
[2)] Grinding wheel from Norton Co.

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 lower than the original tempering temperature.

When EDM'ing larger sizes or complicated shapes *VANADIS 4* 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