VANADIS 6 – SuperClean™ High performance powder metallurgical cold work tool steel

Cover photo:
Powder pressing punch of VANADIS 6.
Excellent results have been obtained for compacting iron powder when abrasive wear reduced the punch life.
(Courtesy GKN Sinter Metals AB, Kolsva.)

Critical tool steel parameters for

GOOD TOOL PERFORMANCE

- Correct hardness for the application
- Very high wear resistance
- High toughness to prevent premature failure due to chipping/crack formation.

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 6 is a powder metallurgical cold work tool steel offering a combination of very high wear resistance and good toughness.

TOOLMAKING

- Machinability
- Heat treatment
- Dimensional stability in heat treatment
- Surface treatment.

Toolmaking with highly alloyed tool steels means that machining and heat treatment have to be considered more than with 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 6* has a similar hardening procedure as the common cold work tool steels. In order to reduce the amount of retained austenite and to optimize the abrasive wear resistance high temperature tempering is recommended. One very big advantage with *VANADIS 6* is that the dimensional stability after hardening and tempering is much better than for conventionally produced cold work steels and HSS used for cold work. This also means that *VANADIS 6* is a tool steel which is very suitable for CVD and PVD coating.

Applications

VANADIS 6 is suitable for long run tooling of work materials where mixed (abrasive–adhesive) or abrasive wear and/or chipping/cracking and/or plastic deformation are dominating failure mechanisms.

Examples:

- Blanking and fine blanking of harder work materials
- Forming operations where a high compressive strength is essential
- Powder compacting
- Substrate steel for surface coating
- Plastics molds and tooling subjected to abrasive wear conditions
- Knives.

General

VANADIS 6 is a chromium-molybdenum-vanadium alloyed PM steel which is characterized by:

- Very high abrasive-adhesive wear resistance
- High compressive strength
- Good toughness
- Very good dimensional stability at heat treatment and in service
- Very good through-hardening properties
- Good resistance to tempering back
- High cleanliness.

Typical analysis %	C 2.1	Si 1.0	Mn 0.4	Cr 6.8	Mo 1.5	V 5.4
Delivery condition	Soft annealed to approx. 255 HB					
Color code	Green/Dark green					

Raufoss Teknologi AS, Verktygsfabriken, Norway.

Properties

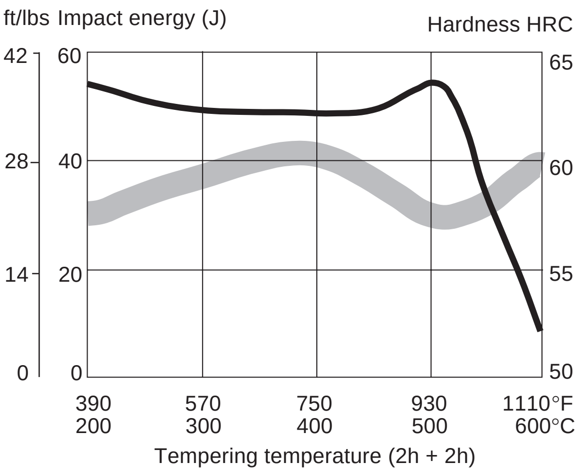
PHYSICAL DATA

Hardened and tempered to 60 HRC.

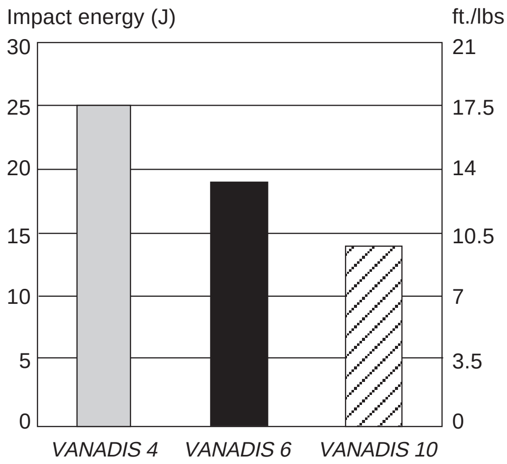
Temperature	68°F (20°C)	390°F (200°C)	750°F (400°C)
Density lbs/in³ kg/m³	0.27 7 610	– –	– –
Modulus of elasticity psi MPa	32.6×10^6 225 000	30.4×10^6 210 000	27.5×10^6 190 000
Coefficient of thermal expansion per °F from 68°F °C from 20°C	– –	6.2×10^{-6} 11.2×10^{-6}	6.7×10^{-6} 12.0×10^{-6}
Thermal conductivity Btu in/(ft² h °F) W/m • °C	– –	154 22	175 25
Specific heat capacity Btu/lb°F J/kg °C	0.110 460	– –	– –

IMPACT STRENGTH

Approximate room temperature impact strength at different tempering temperatures.
Specimen size: 0.27 x 0.40 x 2.2" (7 x 10 x 55 mm) unnotched. Hardened at 1920°F (1050°C). Quenched in air. Tempered 2 x 2h.



Approximate room temperature impact strength for *VANADIS 4*, *VANADIS 6* and *VANADIS 10* at 62 HRC. Short transverse direction. High temperature tempered condition



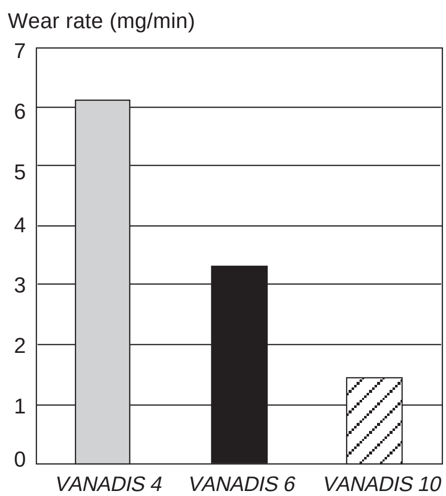
COMPRESSIVE STRENGTH

Hardness	Compressive strength Rc0.2
60 HRC	332 000 psi 2 290 MPa
62 HRC	360 000 psi 2 530 MPa
64 HRC	400 000 psi 2 760 MPa

High temperature tempered, 977°F (525°C) 2 + 2h.

WEAR RESISTANCE

Pin on disc test. Disc material SiO_2. Hardness is 62 HRC for all steels. High temperature tempered condition. Low value is equivalent to good wear resistance.



Heat treatment

SOFT ANNEALING

Protect the steel and heat through to 1650° F (900° C). Then 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) For the higher austenitizing temperatures a second pre-heating step at 1500–1600° F (815–870° C) is recommended
Austenitizing temperature: 1795–2100° F (980–1150° C). Normally 1920° F (1050° C).
Holding time: 30 min. below 2010° F (1100° C), 15 min. above 2010° F (1100° C).

Protect the tool against decarburization and oxidation during hardening.

QUENCHING MEDIA

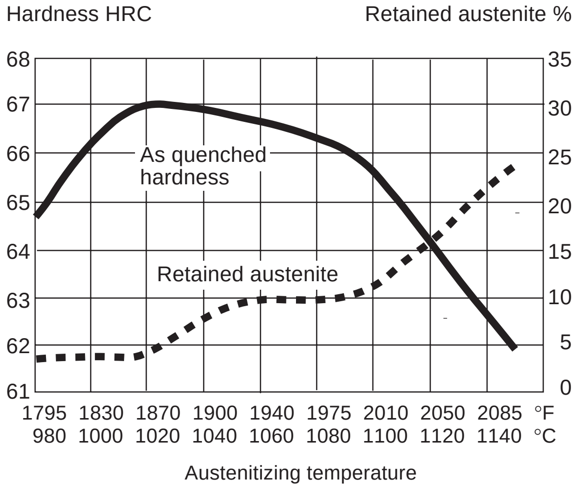
- High speed gas/circulating atmosphere
- Vacuum (high speed gas with sufficient positive pressure), preferably at least 4–5 bar
- Martempering bath or fluidized bed at 930–1020° F (500–550° C)
- Martempering bath or fluidized bed at approx. 390–660° F (200–350° C).

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 concurrent with acceptable distortion.

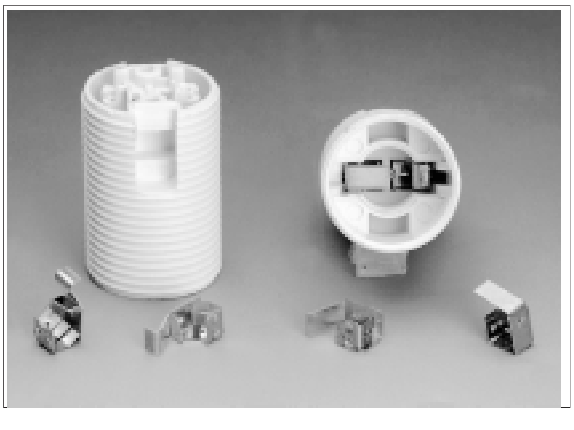
Note 3: Tools with sections >2" (50 mm) should be quenched in sufficient gas pressure and speed. Quenching in still air will result in loss of hardness.

Hardness and retained austenite as functions of austenitizing temperature.



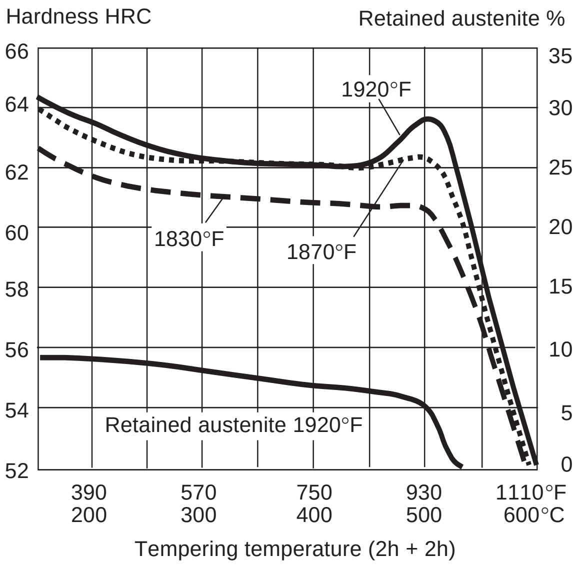
TEMPERING

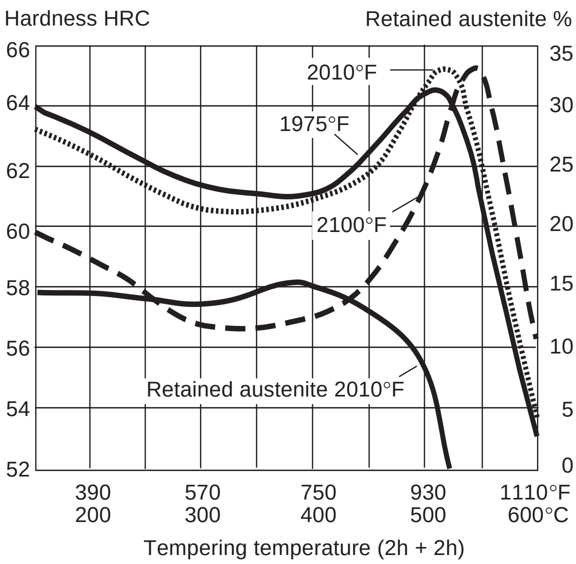
The tempering temperature can be selected according to the hardness required by referencing the tempering graphs on the next page. Temper minimum twice with intermediate cooling to room temperature.
The lowest tempering temperature which should be used is 360° F (180° C). This temperature should only be used for small and uncomplicated tools.
For medium to large size and more complicated tools a temperature of 480° F (250° C) or higher should be used. When performing a high temperature temper, a temperature to the right of the secondary hardening peak should be chosen.
At a hardening temperature of 2010° F (1100° C) or higher *VANADIS 6* must be tempered three times (holding time 1 hour) at minimum 980° F (525° C) in order to reduce the amount of retained austenite. Otherwise the minimum holding time at temperature is 2 hours.



Electrical components blanked with a VANADIS 6 punch.

Tempering graphs





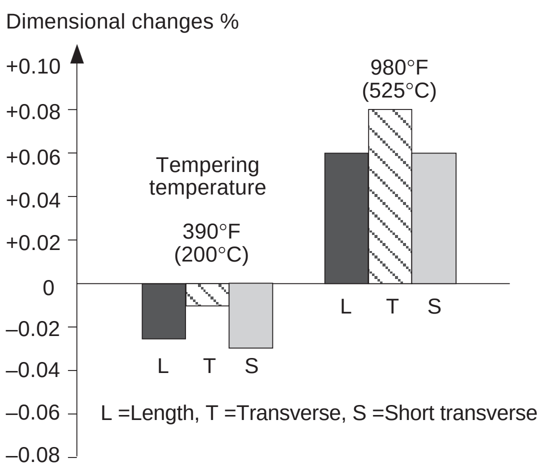
Tempering at high temperature after deep cooling (sub-zero cooling).

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

DIMENSIONAL CHANGES

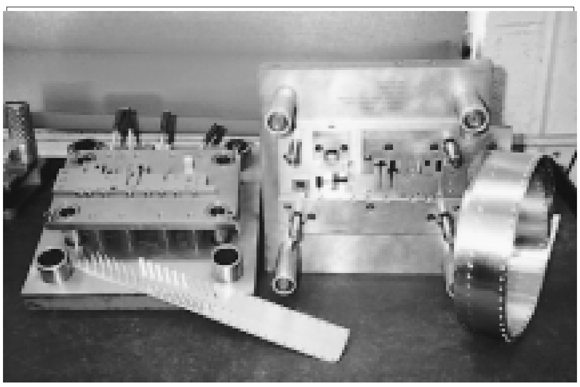
The dimensional changes have been measured after austenitizing at 1050° C/30 min. (1920° F/ 30 min.) followed by gas quenching in a cold chamber vacuum furnace.
Specimen size: 2.5" x 2.5" x 2.5" (65 x 65 x 65 mm)

Austenitizing temperature 1920° F (1050° C)



SUB-ZERO TREATMENT

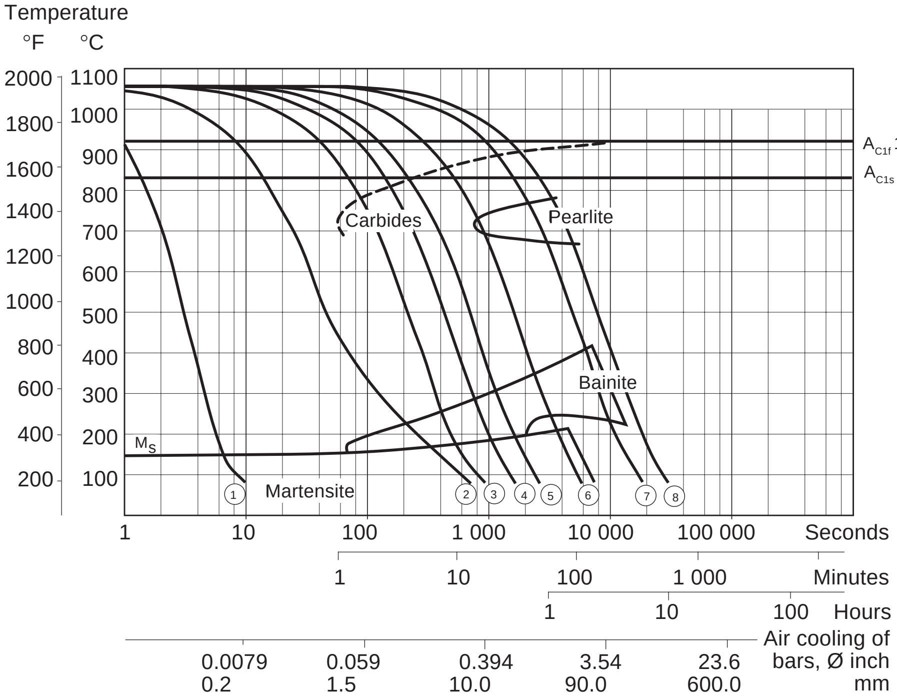
Pieces requiring maximum dimensional stability can be sub-zero treated as follows:
Immediately after quenching the piece should be sub-zero treated to between –95 to –110° F (–70 and –80° C), soaking time 1–3 hours, followed by tempering. The tempering temperature should be lowered 50° F (25° C) in order to get the desired hardness when a high temperature temper is performed. Sub-zero treatment will give a hardness increase of ~1 HRC. Avoid intricate shapes as there will be risk of cracking.
For the highest demands of dimensional stability sub-zero cooling in liquid nitrogen is recommended after quenching and each tempering.



Parts blanked in a VANADIS 6 tool.

CCT-graph

Austenitizing temperature 1920° F (1050° C). Holding time 30 minutes.

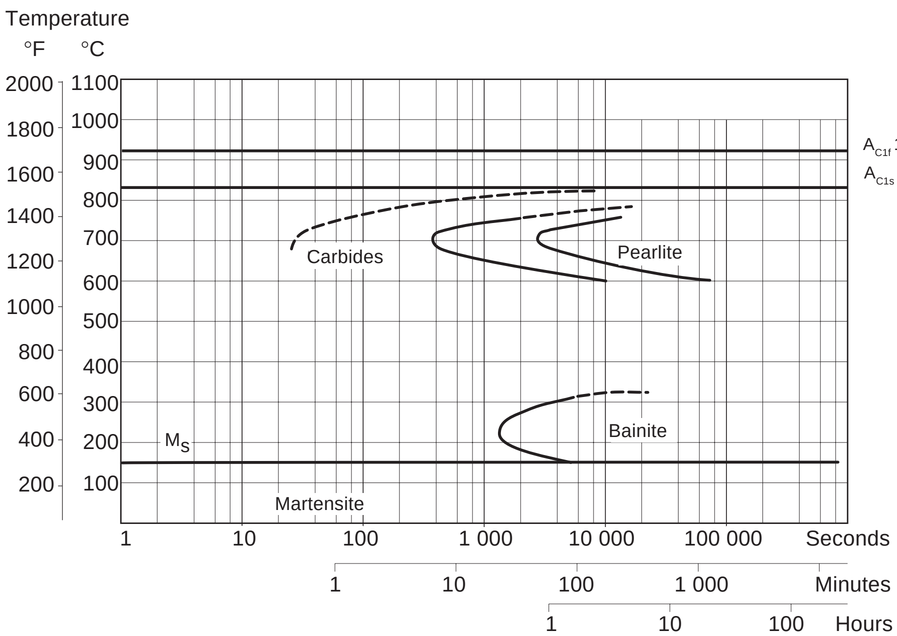


Cooling curve No.	Hardness HV 10	$T_{800-500}$* (sec)
1	870	2
2	870	31
3	870	140
4	870	280
5	870	450
6	762	1030
7	498	3205
8	351	5215

*$T_{800-500}$ = cooling time between 1472–935°F

TTT-graph

Austenitizing temperature 1920° F (1050° C). Holding time 30 minutes.



Temp. °C.	Time hours	Hardness HV10
800	2.25	824
750	4.08	306
700	0.48	394
650	2.17	464
600	16.56	882
450	6.41	882
400	16.35	920
350	16.35	870
300	2.15	857
250	5.42	642
200	2.13	870

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 or CVD.
The high hardness and toughness together with a good dimensional stability makes *VANADIS 6* ideal as a substrate steel for various surface coatings.

NITRIDING AND NITROCARBURIZING

Nitriding and nitrocarburizing result in a hard surface layer which is very resistant to wear and galling.

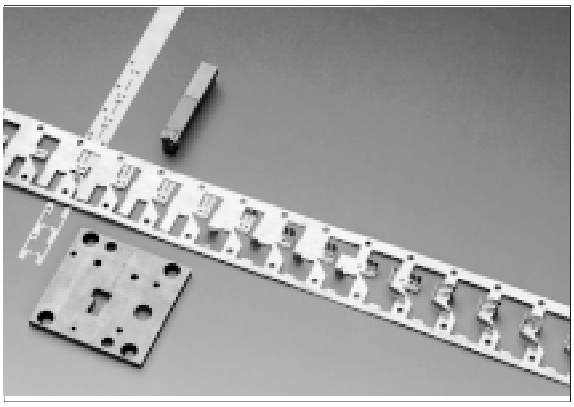
The surface hardness after nitriding is approximately 1250 $HV_{0,2\ kg}$. The thickness of the layer should be chosen carefully, considering the high content of alloying elements, to suit the application in question.

PVD

Physical vapor 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.



Blanked parts. Punch in VANADIS 6, die in VANADIS 10.

Machining recommendations

The cutting data below, valid for *VANADIS 6* in soft annealed condition, 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) f.p.m.	230–330	230–395	23–33
m/min.	70–100	100–120	8–10
Feed (f) i.p.r.	0.012–0.023	– 0.012	– 0.012
mm/r	0.3–0.6	– 0.3	– 0.3
Depth of cut (a_p) inch	0.08–0.23	– 0.08	– 0.08
mm	2–6	– 2	– 2
Carbide designation US	C3	C3	–
ISO	K20 Coated carbide	K15 Coated carbide	–

DRILLING

High speed steel twist drill

Drill diameter inch	Drill diameter mm	Cutting speed (v_c) f.p.m.	Cutting speed (v_c) m/min	Feed (f) i.p.r.	Feed (f) mm/r
–3/16	– 5	26*	8*	0.002–0.004	0.05–0.10
3/16–3/8	5–10	26*	8*	0.004–0.008	0.10–0.20
3/8–5/8	10–15	26*	8*	0.008–0.010	0.20–0.25
5/8–3/4	15–20	26*	8*	0.010–0.012	0.25–0.30

** For coated HSS drills v_c ~46 f.p.m. (14 m/min.).*

Carbide drill

Cutting data parameters	Type of drill: Indexable insert	Solid carbide	Brazed carbide[1)]
Cutting speed (v_c) f.p.m.	300–395	200	100
m/min.	90–120	60	3
Feed (f) i.p.r.	0.002–0.01[2)]	0.004–0.01[2)]	0.006–0.01[2)]
mm/r	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) f.p.m.	165–230	230–330	40
m/min.	50–70	70–100	12
Feed (f_z) in/tooth	0.008–0.016	0.004–0.008	0.004
mm/tooth	0.2–0.4	0.1–0.2	0.1
Depth of cut (a_p) inch	0.08–0.2	0.04–0.08	– 0.08
mm	2–4	1–2	– 2
Carbide designation US	C3	C3	–
ISO	K20 Coated carbide	K15 Coated carbide	–

End milling

Cutting data parameters	Type of milling: Solid carbide	Carbide indexable insert	High speed steel
Cutting speed (v_c) f.p.m.	130	200–260	23[1)]
m/min.	40	70–90	7[1)]
Feed (f_z) in/tooth	0.001–0.008[2)]	0.003–0.008[2)]	0.002–0.014[2)]
mm/tooth	0.03–0.2[2)]	0.08–0.2[2)]	0.05–0.35[2)]
Carbide designation US	C3–C5	C3	–
ISO	K10, P40	K15	–

[1)] For coated HSS end mill $v_c \approx$ 76 f.p.m. (23 m/min.).
[2)] Depending on radial depth of cut and cutter 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 A 46 GV
Face grinding segments	A 36 GV	A 46 GV
Cylindrical grinding	A 60 KV	B151 R50 B3 A 60 JV
Internal grinding	A 60 JV	B151 R75 B3 A 60 IV
Profile grinding	A 100 IV	B126 R100 B6 A 100 JV

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. 50°F (25°C) lower than the original tempering temperature.

When EDM'ing larger sizes or complicated shapes *VANADIS 6* should be tempered at high temperatures, above 930°F (500°C).

Further information

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

Relative comparison of Uddeholm cold work tool steel

MATERIAL PROPERTIES AND RESISTANCE TO FAILURE MECHANISMS