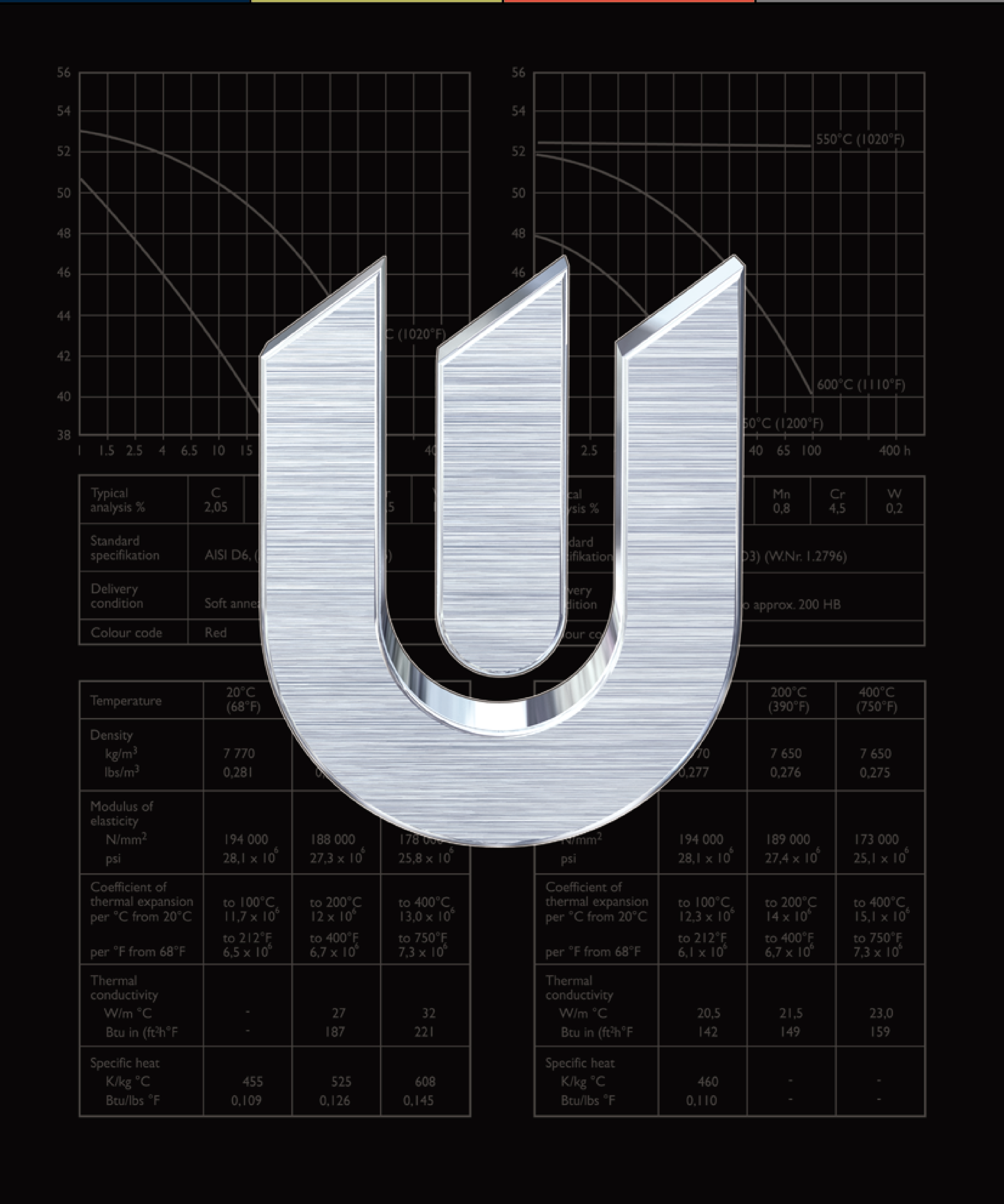
DIEVAR®

Premium hot work tool steel



General

Dievar is a high performance chromium-molybde-num-vanadium alloyed hot work tool steel which offers a very good resistance to heat checking, gross cracking, hot wear and plastic deformation. *Dievar* is characterized by:

- Excellent toughness and ductility in all directions
- Good temper resistance
- Good high-temperature strength
- Excellent hardenability
- Good dimensional stability throughout heat treatment and coating operations.

Standard specification	Cr-Mo-V alloyed hot work tool steel
Delivery condition	Soft annealed to approx. 160 HB
Colour code	Grey/yellow

IMPROVED TOOLING PERFORMANCE

Dievar is a premium hot work tool steel developed by Uddeholm. It is manufactured utilizing the very latest in production and refining techniques. The Dievar development has yielded a die steel with the ultimate resistance to heat checking, gross cracking, hot wear and plastic deformation. The unique properties profile for Dievar makes it the best choice for die casting, forging and extrusion.

Hot work applications

Heat checking is one of the most common failure mechanism e.g. in die casting and now days also in forging applications. Dievar's superior ductility yields the highest possible level of heat checking resistance. With Dievar's outstanding toughness and hardenability the resistance to heat checking can further be improved. If gross cracking is not a factor then a higher working hardness can be utilized (+2 HRC).

Regardless of the dominant failure mechanism; e.g. heat checking, gross cracking, hot wear or plastic deformation. Dievar offers the potential for significant improvements in die life and then resulting in better tooling economy.

Dievar is the material of choice for the high demand die casting-, forging- and extrusion industries.

TOOLS FOR DIE CASTING

Part	Aluminium, magnesium alloys
Dies	44–50 HRC

TOOLS FOR EXTRUSION

Part	Copper, copper alloys HRC	Aluminium, magnesium alloys HRC
Dies	–	46–52
Liners, dummy blocks, stems	46–52	44–52

TOOLS FOR HOT FORGING

Part	Steel, Aluminium
Inserts	44–52 HRC

Properties

The reported properties are representative of samples which have been taken from the centre of a 610 x 203 mm (24" x 8") bar. Unless otherwise is indicated all specimens have been hardened at 1025°C (1875°F), quenched in oil and tempered twice at 625°C (1160°F) for two hours; yielding a working hardness of 44–46 HRC.

PHYSICAL PROPERTIES

Data at room and elevated temperatures.

Temperature	20°C (68°F)	400°C (750°F)	600°C (1110°F)
Density, kg/m³ lbs/in³	 7 800 0,281	 7 700 0,277	 7 600 0,274
Modulus of elasticity MPa psi	 210 000 30,5 x 10⁶	 180 000 26,1 x 10⁶	 145 000 21,0 x 10⁶
Coefficient of thermal expansion per °C from 20°C per °F from 68°F	 – –	 12,7 x 10⁻⁶ 7,0 x 10⁻⁶	 13,3 x 10⁻⁶ 7,3 x 10⁻⁶
Thermal conductivity W/m °C Btu in/(ft²h°F)	 – –	 31 216	 32 223

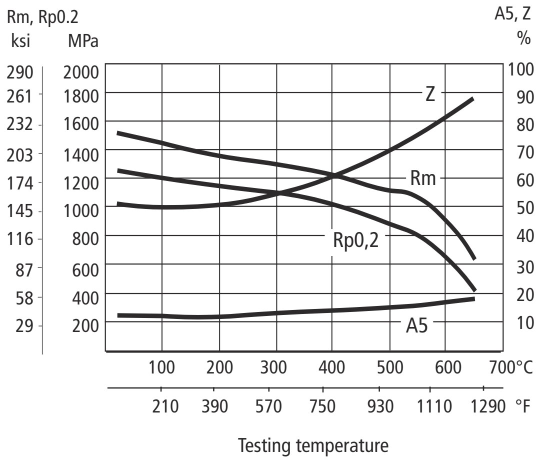
MECHANICAL PROPERTIES

Tensile properties at room temperature, short transverse direction.

Hardness	44 HRC	48 HRC	52 HRC
Tensile strength, R_m	1480 MPa 96 tsi 214 000 psi	1640 MPa 106 tsi 237 000 psi	1900 MPa 123 tsi 275 000 psi
Yield strength, $R_{p0,2}$	1210 MPa 78 tsi 175 000 psi	1380 MPa 89 tsi 200 000 psi	1560 MPa 101 tsi 226 000 psi
Elongation, A_5	13 %	13 %	12,5 %
Reduction of area, Z	55 %	55 %	52 %

Tensile properties at elevated temperature.

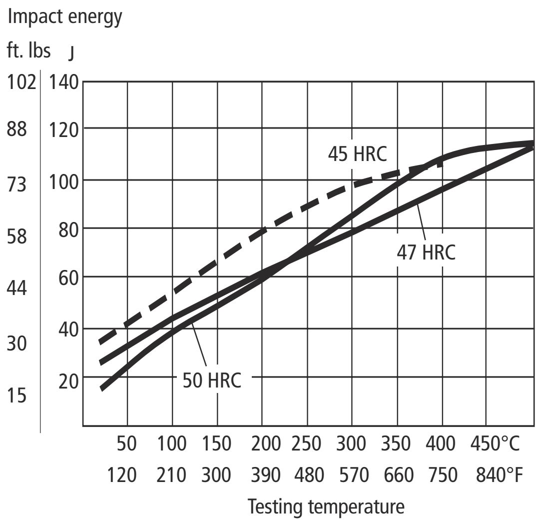
Short transverse direction.

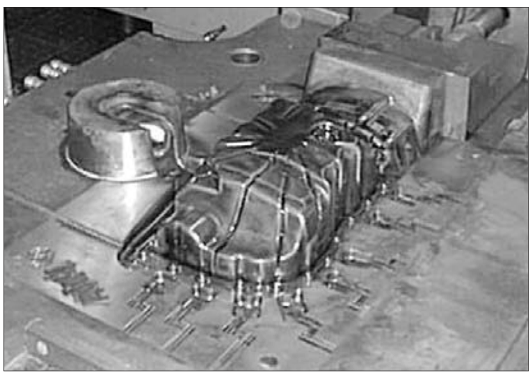


Minimum average unnotched impact ductility is 300 J (220 ft lbs) in the short transverse direction at 44–46 HRC.

Charpy V-notch impact toughness at elevated temperature.

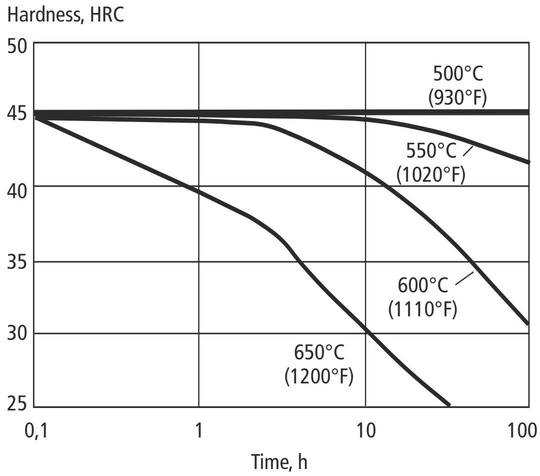
Short transverse direction.





Temper resistance

The specimens have been hardened and tempered to 45 HRC and then held at different temperatures from 1 to 100 hours.



Heat treatment—general recommendations

SOFT ANNEALING

Protect the steel and heat through to 850°C (1560°F). Then cool in furnace at 10°C (20°F) per hour to 600°C (1110°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

Preheating temperature: 600–900°C (1110–1650°F). Normally a minimum of two preheats, the first in the 600–650°C (1110–1200°F) range, and the second in the 820–850°C (1510–1560°F) range. When three preheats are used the second is carried out at 820°C (1510°F) and the third at 900°C (1650°F).

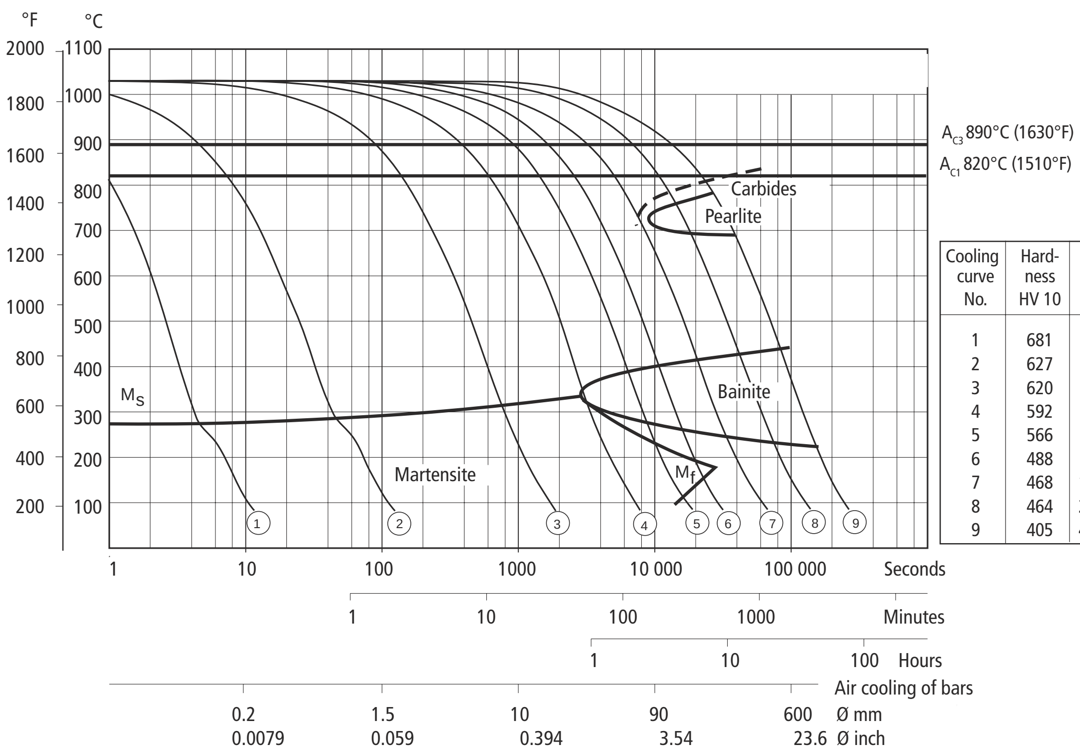
Austenitizing temperature: 1000–1030°C (1830–1890°F).

Temperature °C	Temperature °F	Soaking time minutes	Hardness before tempering
1000	1830	30	52 ±2 HRC
1025	1875	30	55 ±2 HRC

Soaking time = time at hardening temperature after the tool is fully heated through.

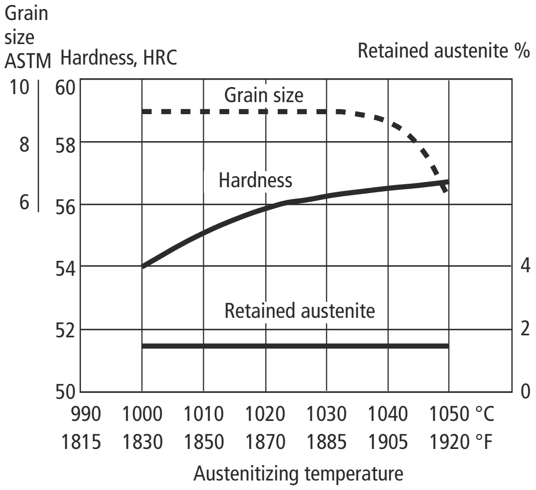
Protect the tool against decarburization and oxidation during austenitizing.

CCT graph—Austenitizing temperature 1025°C (1875°F). Holding time 30 minutes.



Cooling curve No.	Hardness HV 10	$T_{800-500}$ (sec)
1	681	1,5
2	627	15
3	620	280
4	592	1 248
5	566	3 205
6	488	5 200
7	468	10 400
8	464	20 800
9	405	41 600

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



QUENCHING

As a general rule, quench rates should be as rapid as possible. Accelerated quench rates are required to optimize tool properties specifically with regards to toughness and resistance to gross cracking. However, risk of excessive distortion and cracking must be considered

Quenching media

The quenching media should be capable of creating a fully hardened microstructure. Different quench rates for *Dievar* are defined by the CCT graph, page 5.

Recommended quenching media

- High speed gas/circulating atmosphere.
- Vacuum (high speed gas with sufficient positive pressure). An interrupted quench at 320–450°C (610–840°F) is recommended where distortion control and quench cracking are a concern.
- Martempering bath, salt bath or fluidized bed at 450–550°C (840–1020°F).
- Martempering bath, salt bath or fluidized bed at 180–200°C (360–390°F).
- Warm oil, approx. 80°C (180°F).

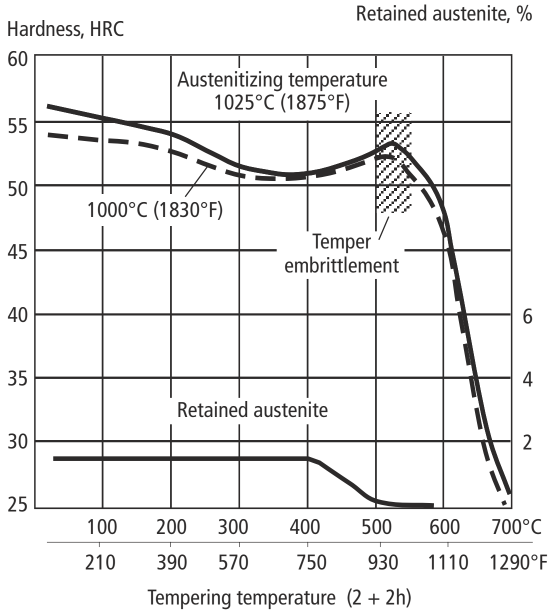
Note: Temper the tool as soon as its temperature reaches 50–70°C (120–160°F).

TEMPERING

Choose the tempering temperature according to the hardness required by reference to the tempering graph below. Temper minimum three times for die casting dies and minimum twice for forging and extrusion tools with intermediate cooling to room temperature. Holding time at temperature minimum 2 hours.

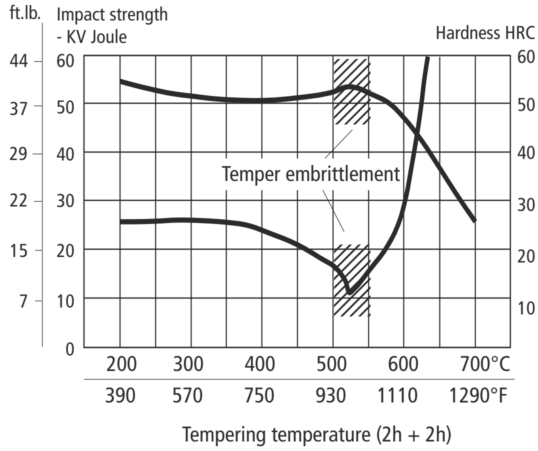
To avoid temper embrittlement tempering in the range of 500–550°C (930–1020°F) is not recommended .

Tempering graph



Effect of tempering temperature on room temperature Charpy V notch impact energy

Short transverse direction.



DIMENSIONAL CHANGES DURING HARDENING AND TEMPERING

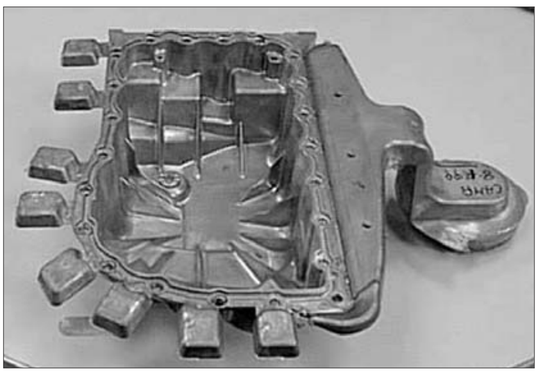
During hardening and tempering the tool is exposed to both thermal and transformation stresses. These stresses will result in distortion. Insufficient levels of machine stock may result in slower than recommended quench rates during heat treatment. In order to predict maximum levels of distortion with a proper quench, a stress relief is always recommended between rough and semi-finish machining, prior to hardening.
For a stress relieved Dievar tool a minimum machine stock of 0,3% is recommended to account for acceptable levels of distortion during a heat treatment with a rapid quench.

NITRIDING AND NITROCARBURIZING

Nitriding and nitrocarburizing result in a hard surface layer which has the potential to improve resistance to wear and soldering, as well as resistance to premature heat checking. Dievar can be nitrided and nitrocarburized via a plasma, gas, fluidized bed, or salt process. The temperature for the deposition process should be 50–90°F (25–50°C) below the highest previous tempering temperature, depending upon the process time and temperature. Otherwise a permanent loss of core hardness, strength, and/or dimensional tolerances may be experienced.

During nitriding and nitrocarburizing, a brittle compound layer, known as the white layer, may be generated. The white layer is very brittle and may result in cracking or spalling when exposed to heavy mechanical or thermal loads. As a general rule the white layer formation must be avoided.

Nitriding in ammonia gas at 510°C (950°F) or plasma nitriding at 480°C (895°F) both result in a surface hardness of approx. 1000 $HV_{0,2}$. In general, plasma nitriding is the preferred method because of better control over nitrogen potential. However, careful gas nitriding can give same results.



The surface hardness after nitrocarburizing in either gas or salt bath at 580°C (1075°F) is approx. 900 $HV_{0,2}$.

DEPTH OF NITRIDING

Process	Time	Depth	Hardness $HV_{0.2}$
Gas nitriding at 510°C (950°F)	10 h	0,16 mm 0,0063 inch	1000
	30 h	0,22 mm 0,0087 inch	
Plasma nitriding at 480°C (895°F)	10 h	0,15 mm 0,0059 inch	1000
Nitrocarburizing – in gas at 580°C (1075°F)	2 h	0,13 mm 0,0051 inch	900
– in salt bath at 580°C (1075°F)	1 h	0,08 mm 0,0031 inch	

* *Depth of case = distance from surface where hardness is 50 $HV_{0,2}$ over base hardness.*

Cutting data recommendations

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

Condition: Soft annealed to ~160 HB

TURNING

Cutting data parameters	Turning with carbide		Turning with high speed steel
	Rough turning	Fine turning	Fine turning
Cutting speed (v_c) m/min f.p.m.	150–200 490–655	200–250 655–820	15–20 50–65
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	0,5–2 0,02–0,08
Carbide designation ISO US	P20–P30 C6–C5 Coated carbide	P10 C7 Coated carbide or cermet	– –

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.	130–180 430–590	180–220 590–720
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 US	P20–P40 C6–C5 Coated carbide	P10 C7 Coated carbide or cermet

End milling

Cutting data parameters	Type of milling		
	Solid carbide	Carbide indexable insert	High speed steel
Cutting speed (v_c) m/min f.p.m.	130–170 425–560	120–160 390–520	25–30[1)] 80–100[1)]
Feed (f_z) mm/tooth inch/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 US	–	P20–P30 C6–C5	– –

[1)] *For coated HSS end mill v_c 45–50m/min. (150 –160 f.p.m.).*
[2)] *Depending on radial depth of cut and cutter diameter.*

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	15–20*	49–66*	0,05–0,15	0,002–0,006
5–10	3/16–3/8	15–20*	49–66*	0,15–0,20	0,006–0,008
10–15	3/8–5/8	15–20*	49–66*	0,20–0,25	0,008–0,010
15–20	5/8–3/4	15–20*	49–66*	0,25–0,35	0,010–0,014

[1)] *For coated HSS drill v_c ~35–40 m/min. (110–130 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.	180–220 590–720	120–150 390–490	60–90 195–295
Feed (f) mm/r i.p.r.	0,05–0,25[2)] 0,002–0,01[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 carbide tip.*
[2)] *Depending on drill diameter.*

Cutting data recommendations

The cutting data below should be considered as guidelines only. These guidelines must be adapted to local machining conditions.

Condition: Hardened and tempered to 44–46 HRC

TURNING

Cutting data parameters	Turning with carbide	
	Rough turning	Fine turning
Cutting speed (v_c) m/min f.p.m.	 40–60 130–195	 70–90 230–295
Feed (f) mm/r i.p.r.	 0,2–0,4 0,008–0,016	 0,05–0,2 0,002–0,008
Depth of cut (a_p) mm inch	 1–2 0,04–0,08	 0,5–1 0,02–0,04
Carbide designation ISO US	 P20–P30 C6–C5 Coated carbide	 P10 C7 Coated carbide or mixed ceramic

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.	 50–90 160–295	 90–130 295–425
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 US	 P20–P40 C6–C5 Coated carbide	 P10 C7 Coated carbide or cermet

End milling

Cutting data parameters	Type of milling		
	Solid carbide	Carbide indexable insert	High speed steel TiCN coated
Cutting speed (v_c) m/min f.p.m.	 60–80 195–260	 70–90 230–295	 5–10 16–33
Feed (f_z) mm/tooth inch/tooth	 0,03–0,20[1)] 0,001–0,008[1)]	 0,08–0,20[1)] 0,003–0,008[1)]	 0,05–0,35[1)] 0,002–0,014[1)]
Carbide designation ISO US	 – 	 P10–P20 C6–C5	 – –

[1)] Depending on radial depth of cut and cutter diameter.

DRILLING

High speed steel twist drill (TiCN coated)

Drill diameter		Cutting speed (v_c)		Feed (f)	
mm	inch	m/min	f.p.m.	mm/r	i.p.r.
– 5	–3/16	4–6	13–20	0,05–0,10	0,002–0,004
5–10	3/16–3/8	4–6	13–20	0,10–0,15	0,004–0,006
10–15	3/8–5/8	4–6	13–20	0,15–0,20	0,006–0,008
15–20	5/8–3/4	4–6	13–20	0,20–0,30	0,008–0,012

Carbide drill

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Brazed carbide[1)]
Cutting speed (v_c) m/min f.p.m.	 60–80 195–260	 60–80 195–260	 40–50 130–160
Feed (f) mm/r i.p.r.	 0,05–0,25[2)] 0,002–0,01[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 carbide 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	A 46 HV
Face grinding segments	A 24 GV	A 36 GV
Cylindrical grinding	A 46 LV	A 60 KV
Internal grinding	A 46 JV	A 60 IV
Profile grinding	A 100 LV	A 120 JV

Electrical Discharge Machining

Following the EDM process, the applicable die surfaces are covered with a resolidified layer (white layer) and a rehardened and untempered layer, both of which are very brittle and hence detrimental to die performance.

If EDM is used the white layer must be completely removed mechanically by grinding or stoning. After the finish machining the tool should also then begiven an additional temper at approx. 25°C (50°F) below the highest previous tempering temperature.

Further information is given in the Uddeholm brochure "EDM of Tool Steel".

Welding

Welding of die components can be performed, with acceptable results, as long as the proper precautions are taken during the preparation of the joint, the filler material selection, the preheating of the die, the controlled cooling of the die and the post weld heat treatment processes. The following guidelines summarize the most important welding process parameters.

For more detailed information refer to Uddeholm's "Welding of Tool Steel" brochure.

Welding method	TIG	MMA
Preheating temperature*	325–375°C (620–710°F)	325–375°C (620–710°F)
Filler metals	DIEVAR TIG-WELD QRO 90 TIG-WELD	QRO 90 WELD
Maximum interpass temperature	475°C (880°F)	475°C (880°F)
Post welding cooling	20–40°C/h (35–70°F/h) for the first 2–3 hours and then freely in air.	
Hardness after welding	50–55 HRC	50–55 HRC
Heat treatment after welding		
Hardened condition	Temper at 20°C (35°F) below the highest previous tempering temperature.	
Soft annealed condition	Soft-anneal the material at 850°C (1560°F) in protected atmosphere. Then cool in the furnace at 10°C (20°F) per hour to 600°C (1110°F) then freely in air.	

**Preheating temperature must be established throughout the die and must be maintained for the entirity of the welding process, to prevent weld cracking.*

Further information

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