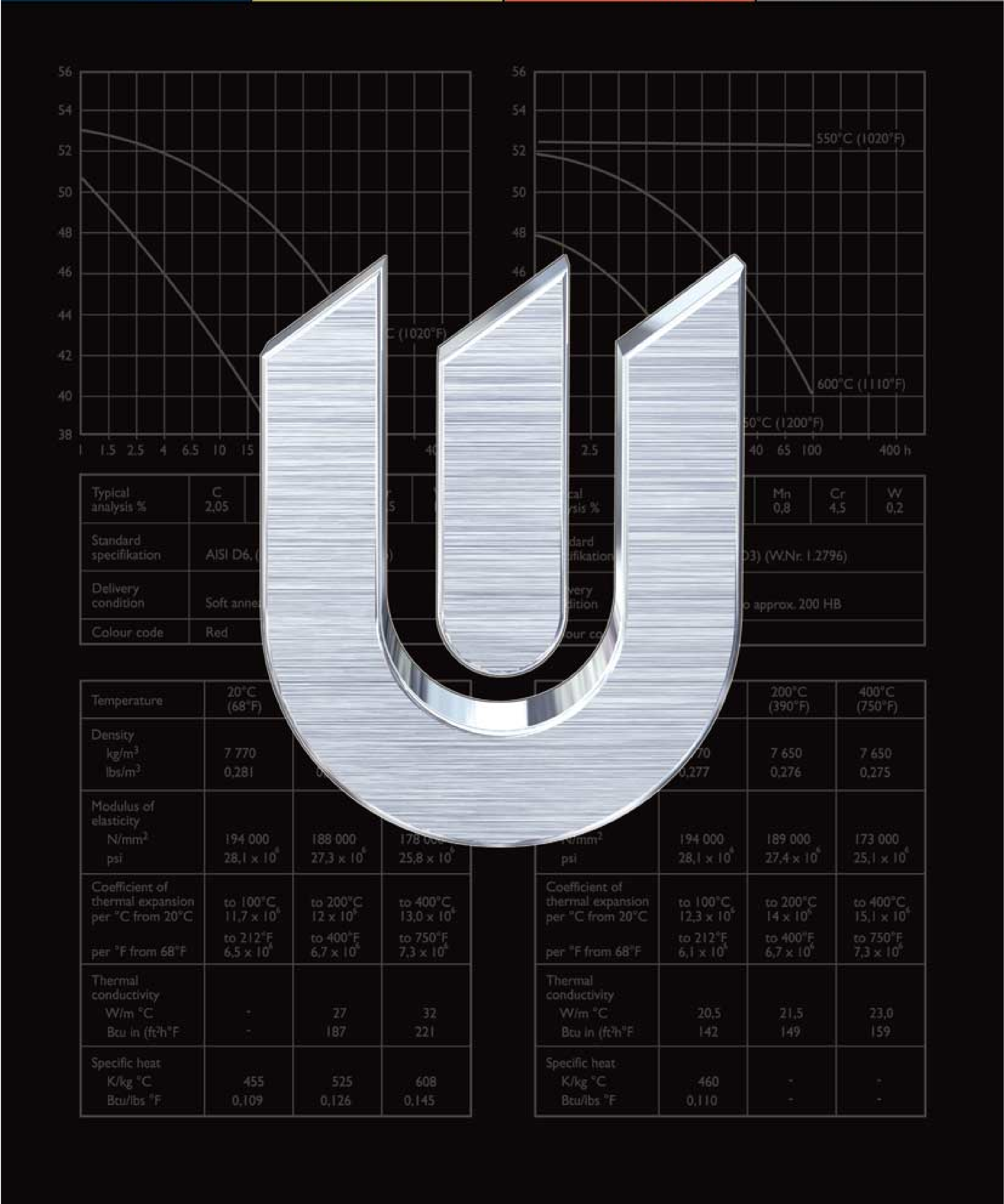
HOTVAR

Hot work tool steel

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



General

HOTVAR is a high performance molybdenum-vanadium alloyed hot-work tool steel which is characterized by:

- High hot wear resistance
- Very good high temperature properties
- High resistance to thermal fatigue
- Very good temper resistance
- Very good thermal conductivity.

Typical analysis %	C 0,55	Si 1,0	Mn 0,75	Cr 2,6	Mo 2,25	V 0,85
Standard specification	None					
Delivery condition	Soft annealed to approx. 210 HB					
Colour code	Red/brown					

IMPROVED TOOLING PERFORMANCE

HOTVAR is a specially premium hot work steel developed by Uddeholm to provide a very good performance in tooling up to 650°C. The alloy elements in *HOTVAR* are balanced to give high hot wear resistance and good high temperature properties. *HOTVAR* is manufactured by special techniques.

Applications

HOTVAR is a hot-work tool steel suitable for applications where hot wear and/or plastic deformation are the dominating failure mechanisms.

Applications and tools of especial interest:

- Warm forging, dies and punches
- Roll forging, rolling segments
- Rock orbital forging, punches and dies
- Upset forging, clamping tools
- Progressive forging, dies
- Axial closed die rolling, top and bottom dies
- Cross forming, segments
- Hot bending, tools
- Hot calibration, tools
- Zinc die casting, dies
- Al-tube extrusion.

Recommended hardness level is 54–58 HRC.
For improving the wear resistance the tools can be plasma nitrided or nitrocarburized.

Properties

All specimens are taken from the centre of a bar 115 mm Ø (4,5”). Unless otherwise is indicated all specimens were hardened at 1050°C (1920°F), quenched in air and tempered 2 + 2 h at 575°C (1070°F) to a hardness corresponding to 56 HRC.

PHYSICAL DATA

Data at room and elevated temperatures.

Temperature	20°C (70°F)	400°C (750°F)	600°C (1110°F)
Density kg/m^3 lbs/in^3	7 800 0,281	7 700 0,277	7 600 0,274
Modulus of elasticity MPa psi	210 000 30,5 x 10^6	180 000 26,1 x 10^6	140 000 20,3 x 10^6
Coefficient of thermal expansion per °C from 20°C °F from 68°F	– –	12,6 x 10^{-6} 7,0 x 10^{-6}	13,2 x 10^{-6} 7,3 x 10^{-6}
Thermal conductivity W/m °C Btu in (ft^{2}h °F)	31 215	33 230	33 230

MECHANICAL PROPERTIES

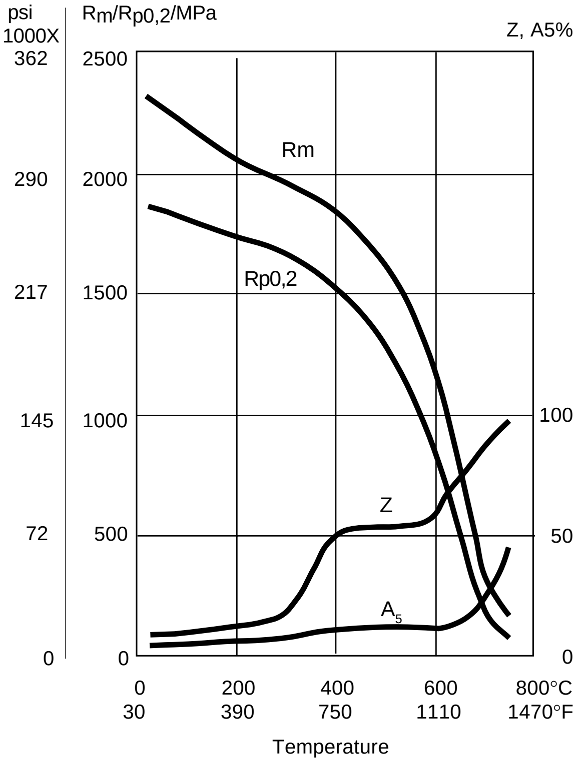
Approximate tensile strength at room temperature.

Hardness	54 HRC	56 HRC	58 HRC
Tensile strength R_m	2 100 MPa 136 tsi 305 000 psi	2 200 MPa 142 tsi 320 000 psi	2 300 MPa 149 tsi 335 000 psi
Yield strength $R_{p0,2}$	1 800 MPa 117 tsi 260 000 psi	1 820 MPa 119 tsi 265 000 psi	1 850 MPa 121 tsi 270 000 psi

Dies for axial closed die rolling.

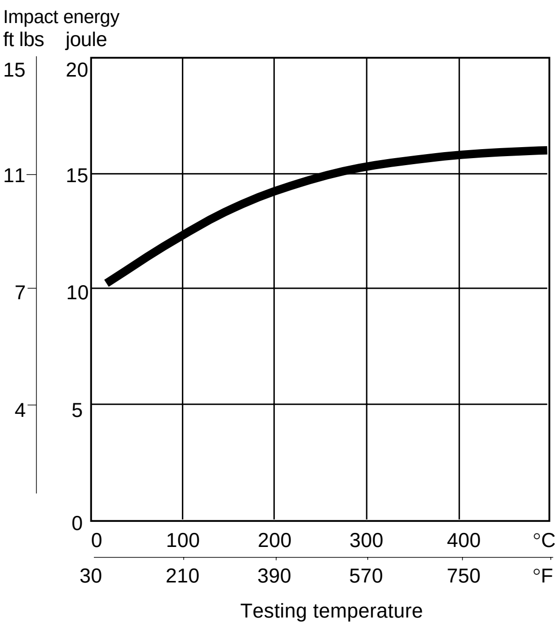
Hot strength

Hot strength in longitudinal direction.



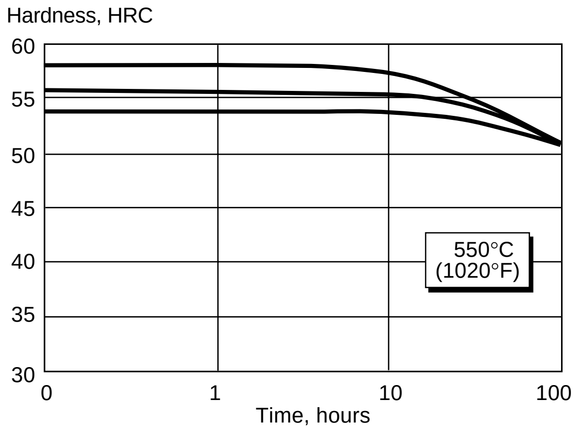
Effect of testing temperature on impact energy

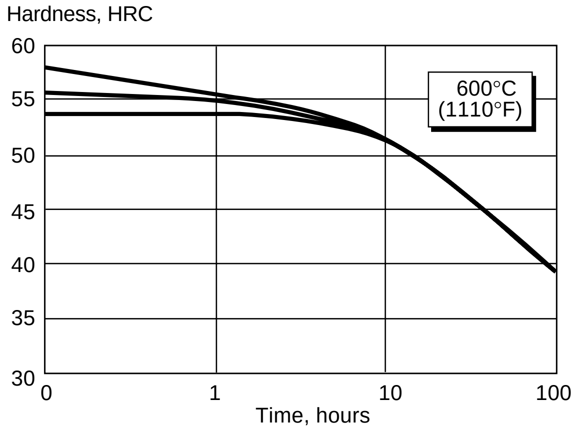
Charpy -V specimens, transverse direction.

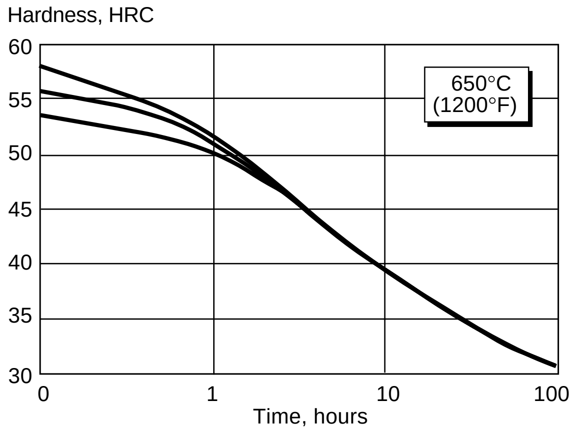


Effect of time at high temperature on hardness

The softening at high temperatures and different holding times are shown below. The specimens have first been hardened and tempered to 54, 56 and 58 HRC.







Heat treatment—general recommendations

SOFT ANNEALING

Protect the steel and heat through to 820°C (1500°F). Then cool in the 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 350°C (660°F), then freely in air.

HARDENING

Pre-heating temperature: first step at 480–600°C (895–1110°F), second step at 850°C (1560°F).
Austenitizing temperature: 1050–1070°C (1920–1960°F), normally 1050°C (1920°F) but when maximum hardness is required the normally temperature is 1070°C (1960°F).

Temperature °C	Temperature °F	Soaking time* minutes	Hardness before temp. for Ø 25 mm (1 inch) Oil	Hardness before temp. for Ø 25 mm (1 inch) Air
1050	1920	30	61 ±1	59 ±1
1070	1960	20	62 ±1	60 ±1

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

Protect the part against decarburization and oxidation during hardening.

QUENCHING MEDIA

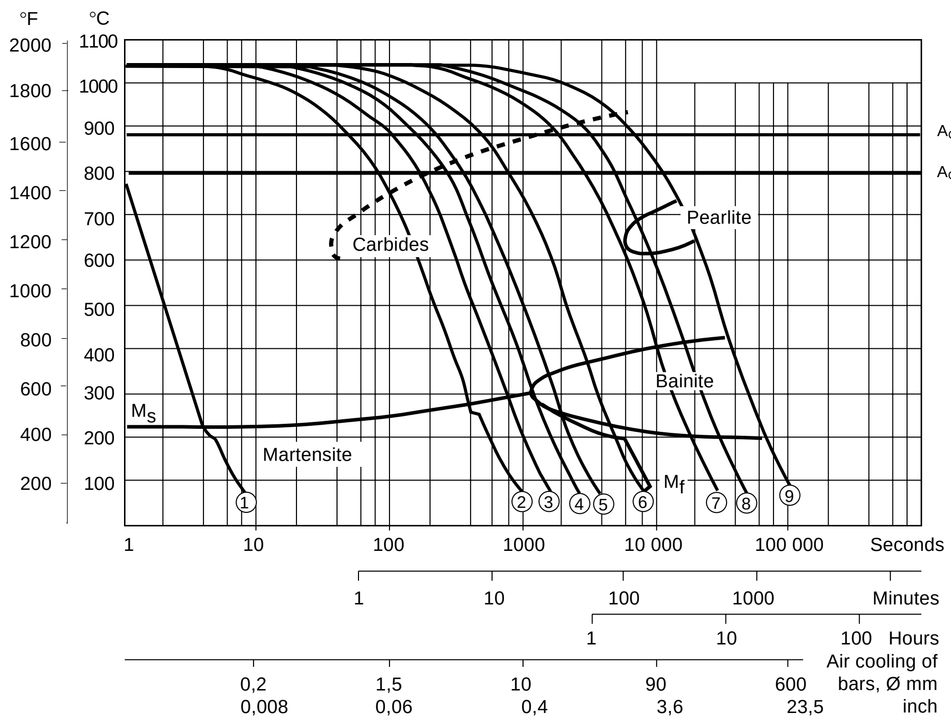
- High speed gas/circulating atmosphere
- Vacuum (high speed gas with sufficient positive pressure)
- Martempering bath or fluidized bed at 450–550°C (840–1020°F)
- Martempering bath or fluidized bed at approx. 180–220°C (360–430°F)
- Warm oil, about 80°C (175°F).

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 fast but not at a level that gives excessive distortion or cracks.

CCT -graph

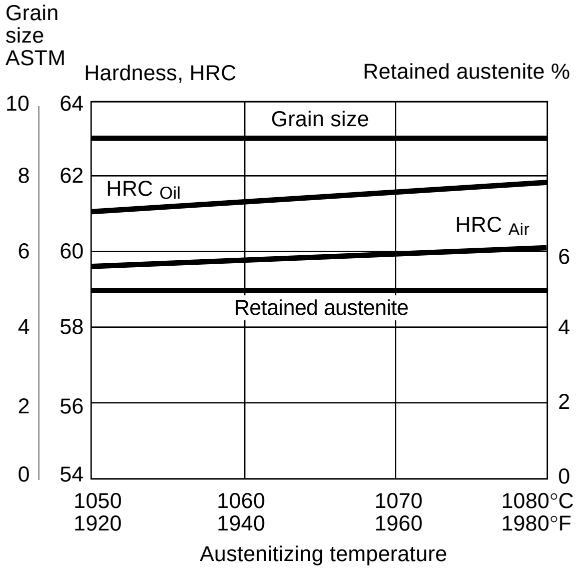
Austenitizing temperature 1050°C (1920°F). Holding time 30 minutes.



Cooling curve No.	Hardness HV_{10}	$T_{800-500}$ (sec)
1	772	1
2	734	140
3	715	280
4	707	450
5	690	630
6	548	1390
7	473	5215
8	464	8360
9	351	19400

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

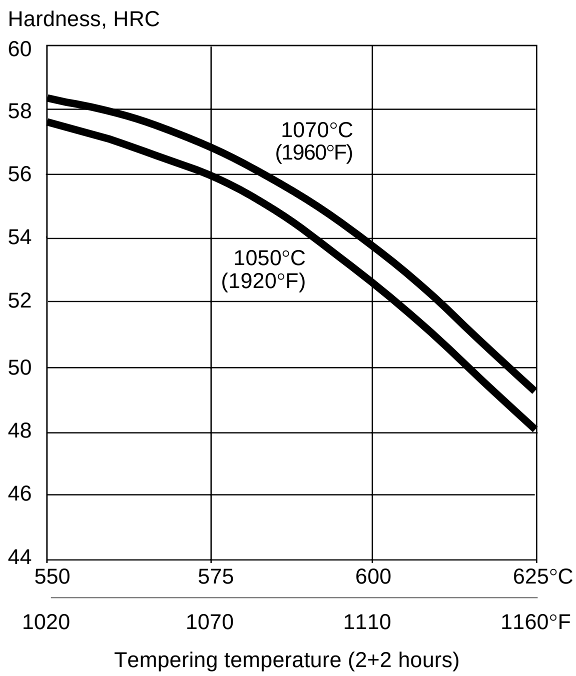
Samples Ø 25 mm (1 inch).



TEMPERING

Choose the tempering temperature according to the hardness required by reference to tempering graph. Temper minimum twice with intermediate cooling to room temperature. Holding time at temperature minimum 2 hours.

Tempering graph



Tempering at 250°C (485°F), 2 + 2h gives a hardness of 56–58 HRC.

DIMENSIONAL CHANGES DURING HARDENING AND TEMPERING

During hardening and tempering the die is exposed to thermal as well as transformation stresses. This will inevitably result in dimensional changes and in the worse case distortion. It is therefore recommended to always leave enough machining allowance after machining before the die is hardened and tempered. Normally the size in the largest direction will shrink and the size in the smallest direction might increase, but this is also a matter of the die size, the die design as well as the cooling rate after hardening.

For *HOTVAR* it is recommend to leave a machining allowance of 0,4 per cent of the dimension in length, width and thickness.

NITRIDING AND NITROCARBURIZING

Nitriding and nitrocarburizing result in a hard surface layer which is very resistant to wear and erosion. The nitrided layer is, however, brittle and may crack or spall when exposed to mechanical or thermal shock, the risk increases with layer thickness. Before nitriding, the tool should be hardened and tempered at a temperature at least 50°C (90°F) above the nitriding temperature.

In general, plasma nitriding is the preferred method because of better control over nitrogen potential. Plasma nitriding at 480°C (895°F) in a 75% hydrogen/25% nitrogen mixture result in a surface hardness of about 1000 $HV_{0,2}$.

HOTVAR can also be nitrocarburized in either gas or salt bath. The surface hardness after nitrocarburizing is about 900 $HV_{0,2}$.

DEPTH OF NITRIDING

Process	Time	Depth mm	inch
Plasma nitriding at 480°C (895°F)	10 30	0,18 0,27	0,0070 0,0106
Nitrocarburizing			
–in gas at 580°C (1075°F)	2,5	0,20	0,0080
–in salt bath at 580°C (1075°F)	1	0,13	0,0050

It should be noted that *HOTVAR* exhibits better nitridability than AISI H13. For this reason, the nitriding times for *HOTVAR* should be shortened in relation to H13, otherwise there is a considerable risk that the case depth will be too great.

Machining recommendations

The cutting data below, valid for *HOTVAR* in soft annealed condition, are to be considered as guiding values which must be adapted to existing local conditions. More detailed information can be found in Uddeholm "Cutting Data Recommendations".

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.	140–160 455–520	160–180 520–590	25 80
Feed (f) mm/r i.p.r.	0,3–0,6 0,01–0,024	–0,3 –0,01	–0,3 –0,01
Depth of cut (a_p) mm inch	2–6 0,08–0,24	–2 –0,08	–2 –0,08
Carbide designation ISO US	P20–P30 C6–C5 Coated carbide	P10 C7 Coated carbide or cermet	– –

DRILLING

High speed steel twist drill

Drill diameter Ø mm	Drill diameter Ø inch	Cutting speed (v_c) m/min.	Cutting speed (v_c) f.p.m.	Feed (f) mm/r	Feed (f) i.p.r.
–5	–3/16	14*	46*	0,08–0,20	0,003–0,008
5–10	3/16–3/8	14*	46*	0,20–0,30	0,008–0,012
10–15	3/8–5/8	14*	46*	0,30–0,35	0,012–0,014
15–20	5/8–3|4	14*	46*	0,35–0,40	0,014–0,016

*) *For coated HSS drill v_c ~20 m/min. (66 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.	160–200 520–650	65 215	55 180
Feed (f) mm/r i.p.r.	0,05–0,25[2] 0,002–0,010[2]	0,10–0,25[2] 0,004–0,010[2]	0,15–0,25[2] 0,006–0,010[2]

[1] *Drill with internal cooling channels and brazed carbide tip.*

[2] *Depending on drill diameter.*

MILLING

Face and square shoulder milling

Cutting data parameters	Milling with carbide		Milling with high speed steel
	Rough milling	Fine milling	Fine milling
Cutting speed (v_c) m/min. f.p.m.	140–180 455–590	180–220 590–720	80 100
Feed (f_z) mm/tooth inch/tooth	0,2–0,4 0,008–0,016	0,1–0,2 0,003–0,007	–0,1 –0,004
Depth of cut (a_p) mm inch	2–5 0,08–0,2	–2 –0,08	–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.	65 210	120–160 390–520	25[1] 80[1]
Feed (f_z) mm/tooth inch/tooth	0,03–0,2[2] 0,001–0,008[2]	0,08–0,2[2] 0,003–0,008[2]	0,05–0,35[2] 0,002–0,014[2]
Carbide designation ISO US	K10, P40 C3–C5	P20–P30 C6–C5	– –

[1] *For coated HSS end mill $v_c \approx$ 40 m/min. (130 f.p.m.).*

[2] *Depending on radial depth of cut and cutter diameter.*

GRINDING

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

Type of grinding	Wheel recommendation Soft annealed condition	Wheel recommendation Hardened condition
Face grinding straight wheel	A 46 HV	A 46 GV
Face grinding segment	A 24 GV	A 36 GV
Cylindrical grinding	A 46 LV	A 60 JV
Internal grinding	A 46 JV	A 60 IV
Profile grinding	A 100 LV	A 120 JV

Electrical-discharge machining

If spark-erosion, EDM, is performed in the hardened and tempered condition, the white re-cast layer should be removed mechanically e.g. by grinding or stoning. The tool should then be given an additional temper at approx. 25°C (50°F) below the previous tempering temperature.
More detailed information can be found in the Uddeholm publication "EDM of Tool Steel".

Welding

Good results when welding tool steel can be achieved if proper precautions are taken during welding (elevated working temperature, joint preparation, choice of consumables and welding procedure).

Welding method	TIG	MMA
Working temperature	325–375°C	325–375°C
Filler metals	QRO 90 TIG-WELD	QRO 90 WELD
Hardness after welding	50–55 HRC	50–55 HRC
Heat treatment after welding		
Hardened condition	Temper at 20°C (40°F) below the original tempering temperature.	
Soft annealed condition	Soft anneal the material at 820°C (1500°F) in protected atmosphere. Then cool in the furnace at 10°C (20°F) per hour to 650°C (1200°F) then free in air.	

More detailed information can be found in the Uddeholm brochure "Welding of Tool Steel".

Further information

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