

# HOTVAR®

Hot work tool steel

COLD WORK

PLASTIC MOULDING

HOT WORK

HIGH PERFORMANCE STEEL



This information is based on our present state of knowledge and is intended to provide general notes on our products and their uses. It should not therefore be construed as a warranty of specific properties of the products described or a warranty for fitness for a particular purpose.

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

### MECHANICAL PROPERTIES

Approximate tensile strength at room temperature.

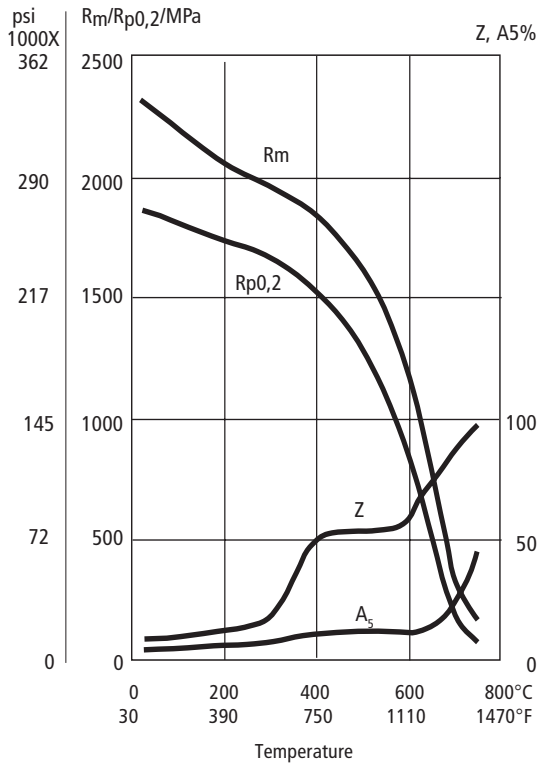
Hardness	54 HRC	56 HRC	58 HRC
Tensile strength Rm	2 100 MPa 136 tsi 305 000 psi	2 200 MPa 142 tsi 320 000 psi	2 300 MPa 149 tsi 335 000 psi
Yield strength Rp0,2	1 800 MPa 117 tsi 260 000 psi	1 820 MPa 119 tsi 265 000 psi	1 850 MPa 121 tsi 270 000 psi



Dies for axial closed die rolling.

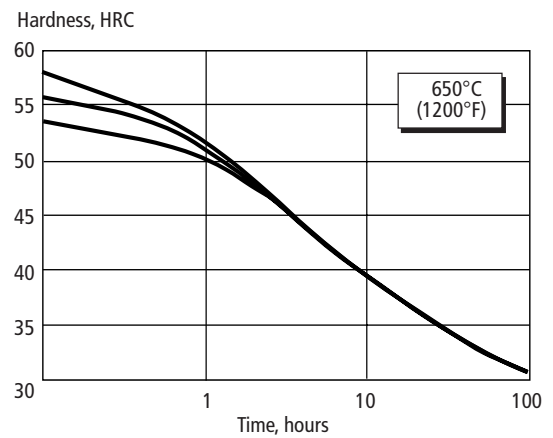
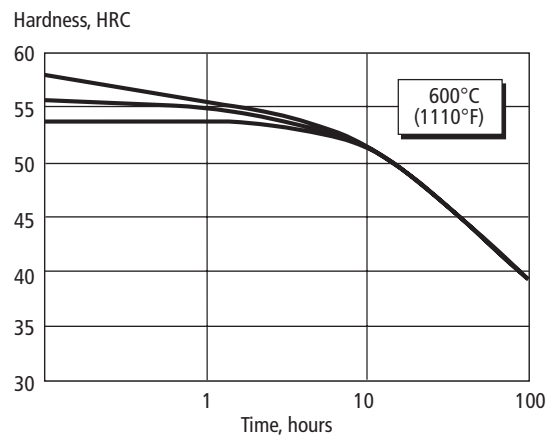
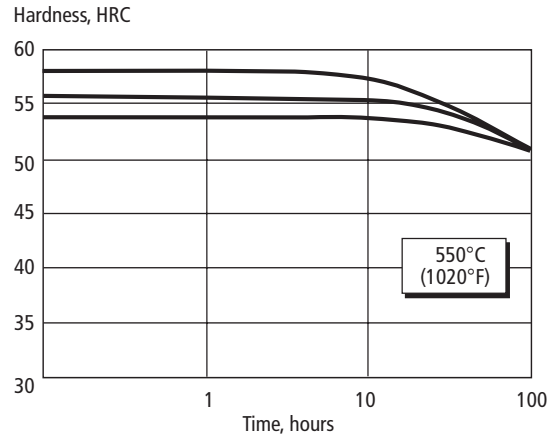
*Hot strength*

Hot strength in longitudinal direction.



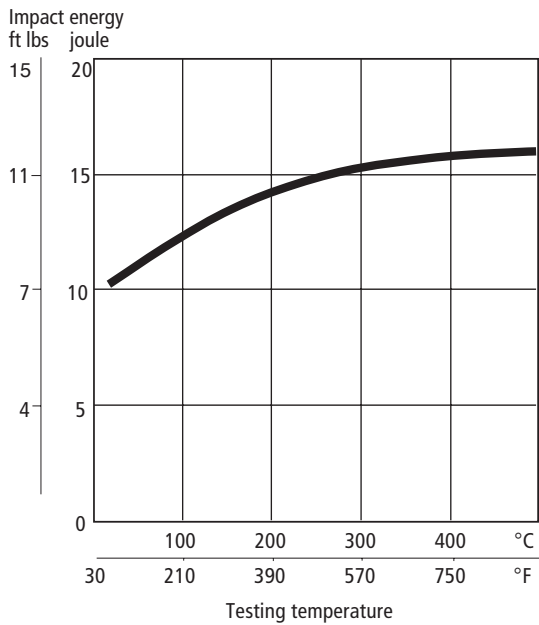
*Effect of time at high temperature on hardness*

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.



*Effect of testing temperature on impact energy*

Charpy -V specimens, transverse direction.



# 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).

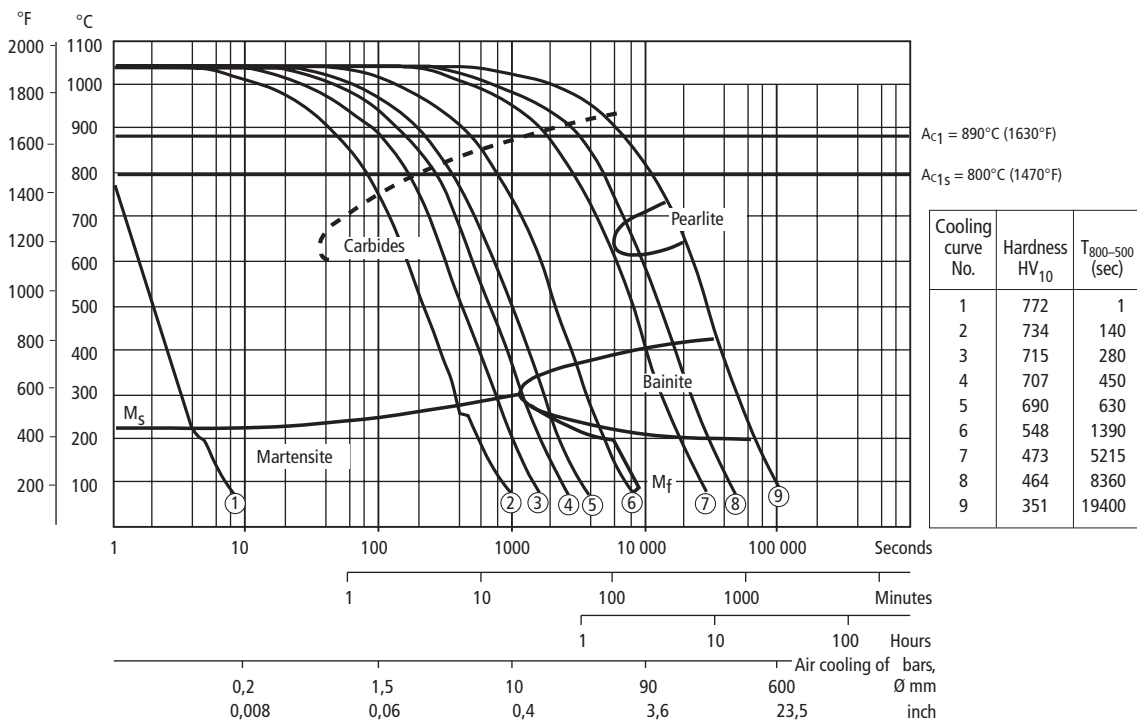
Temperature		Soaking time* minutes	Hardness before temp. for Ø 25 mm (1 inch)	
°C	°F		Oil	Air
1050	1920	30	61 ± 1	59 ± 1
1070	1960	20	62 ± 1	60 ± 1

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

Protect the part against decarburization and oxidation during hardening.

## CCT -graph

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



## QUENCHING MEDIA

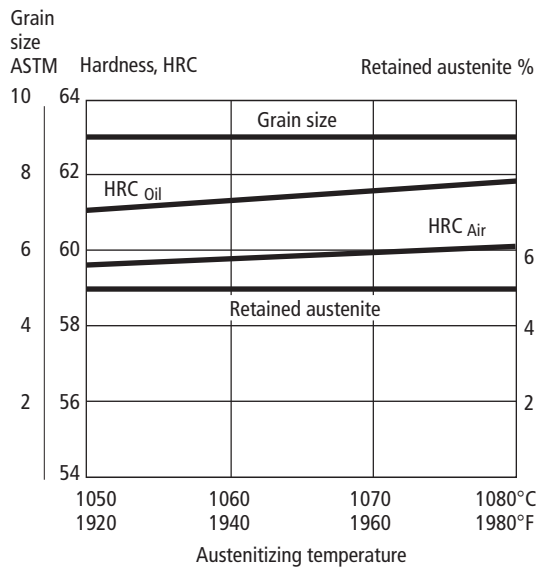
- High speed gas/circulating atmosphere
- Vacuum (high speed gas with sufficient positive pressure)
- Martempering bath or fluidized bed at 450–550°C (840–1020°F)
- Martempering bath or fluidized bed at approx. 180–220°C (360–430°F)
- Warm oil, about 80°C (175°F).

*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.

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

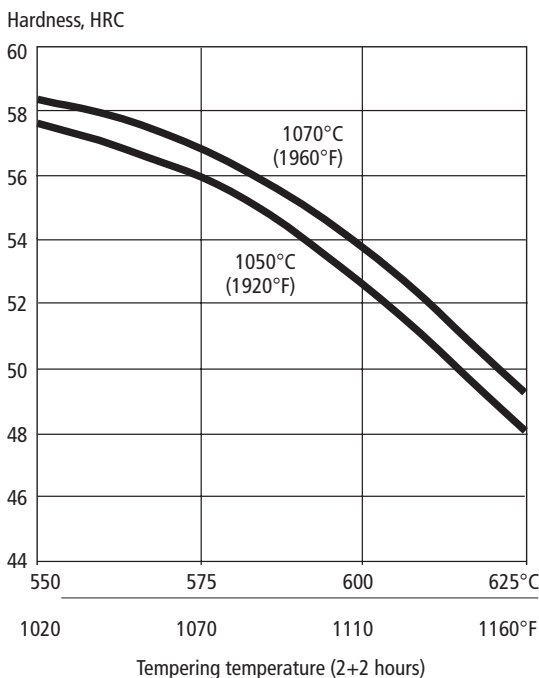
Samples Ø 25 mm (1 inch).



## 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 recommended 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.

Nitriding in ammonia gas at 510°C (950°F) or plasma nitriding at 480°C (895°F) in a 75% hydrogen/25% nitrogen mixture result in a surface hardness of about 1000 HV<sub>0,2</sub>. In general, plasma nitriding is the preferred method because of better control over nitrogen potential.

Hotvar can also be nitrocarburized in either gas or salt bath. The surface hardness after nitrocarburizing is about 900 HV<sub>0,2</sub>.

## DEPTH OF NITRIDING

Process	Time	Depth	
		mm	inch
Plasma nitriding at 480°C (895°F)	10	0,18	0,0070
	30	0,27	0,0106
Nitrocarburizing	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 Fine turning
	Rough turning	Fine turning	
Cutting speed ( $v_c$ ) m/min. f.p.m.	150–170 490–560	170–190 560–620	20–25 65–80
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	0,5–3 0,02–0,12
Carbide designation ISO US	P20–P30 C6–C5 Coated carbide	P10 C7 Coated carbide or cermet	– –

## DRILLING

### High speed steel twist drill

Drill diameter $\varnothing$		Cutting speed ( $v_c$ )		Feed (f)	
mm	inch	m/min.	f.p.m.	mm/r	i.p.r.
–5	–3/16	14–16*	46–50*	0,05–0,15	0,002–0,006
5–10	3/16–3/8	14–16*	46–50*	0,15–0,20	0,006–0,008
10–15	3/8–5/8	14–16*	46–50*	0,20–0,25	0,008–0,010
15–20	5/8–3/4	14–16*	46–50*	0,25–0,35	0,010–0,014

\* For coated HSS drill  $v_c = 18–22$  m/min. (60–70 f.p.m.)

### Carbide drill

Cutting data parameters	Type of drill		
	Indexable insert	Solid carbide	Brazed carbide <sup>1)</sup>
Cutting speed ( $v_c$ ) m/min. f.p.m.	160–200 520–655	130–160 425–520	55–60 180–195
Feed (f) mm/r i.p.r.	0,05–0,25 <sup>2)</sup> 0,002–0,010 <sup>2)</sup>	0,10–0,25 <sup>2)</sup> 0,004–0,010 <sup>2)</sup>	0,15–0,25 <sup>2)</sup> 0,006–0,010 <sup>2)</sup>

<sup>1)</sup> Drill with internal cooling channels and brazed carbide tip

<sup>2)</sup> Depending on drill diameter

## 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.	140–200 460–655	260–240 850–785
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	2–5 0,08–0,2	–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.	110–150 360–490	120–160 390–520	20–25 <sup>1)</sup> 65–80 <sup>1)</sup>
Feed ( $f_z$ ) mm/tooth inch/tooth	0,03–0,2 <sup>2)</sup> 0,001–0,008 <sup>2)</sup>	0,08–0,2 <sup>2)</sup> 0,003–0,008 <sup>2)</sup>	0,05–0,35 <sup>2)</sup> 0,002–0,014 <sup>2)</sup>
Carbide designation ISO US	K10, P40 C3–C5	P20–P30 C6–C5	– –

<sup>1)</sup> For coated HSS end mill  $v_c = 35–40$  m/min. (115–130 f.p.m.)

<sup>2)</sup> 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	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 KV
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
<b>Heat treatment after welding</b>		
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.

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