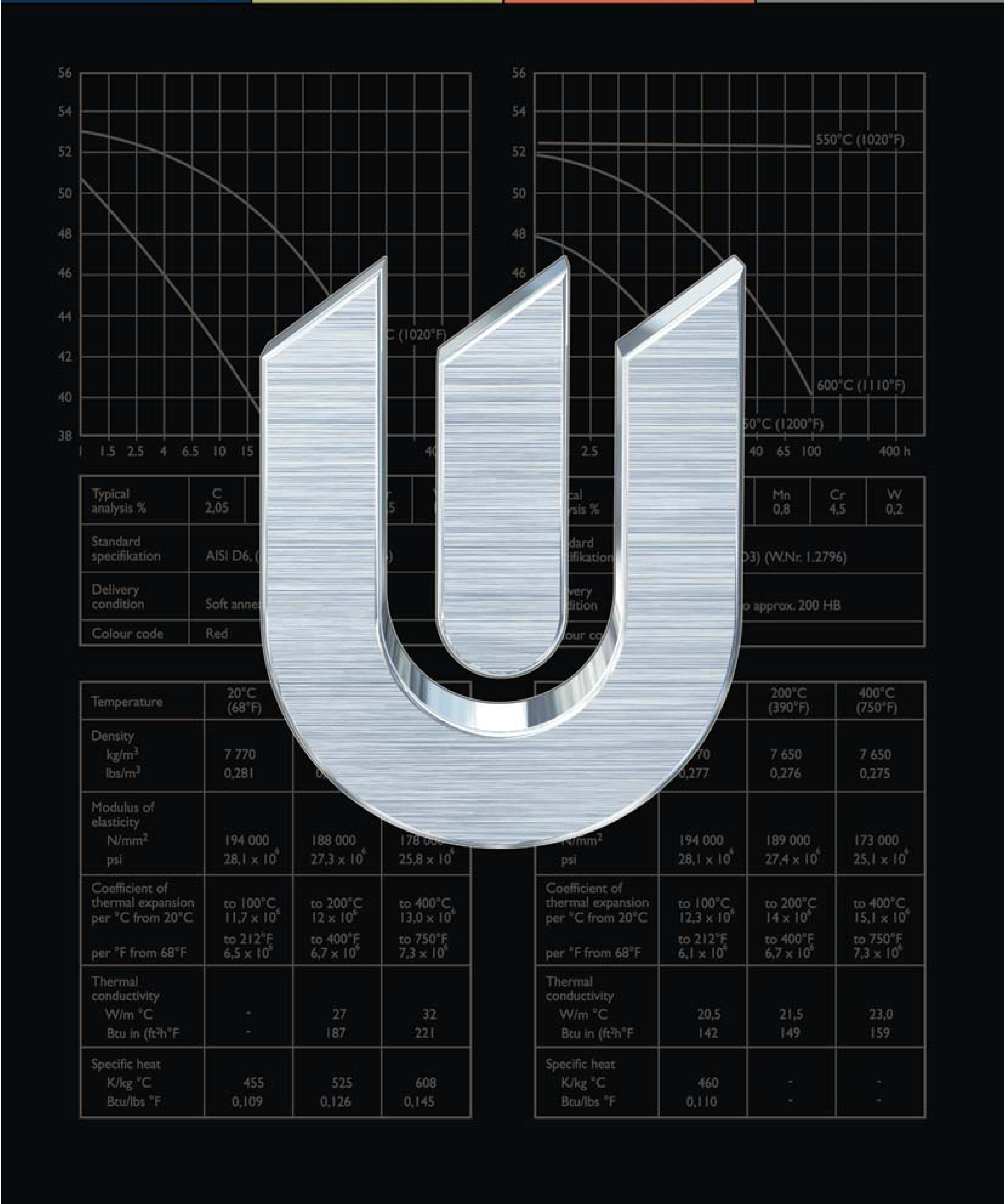
ORVAR® SUPERIOR

Superior Quality Hot Work Tool Steel

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



General

Orvar Superior is a chromium-molybdenum-vanadium-alloyed steel which is characterized by:

- A high level of resistance to thermal shock and thermal fatigue
- Good high-temperature strength
- Excellent toughness and ductility **in all directions**
- Good machinability and polishability
- Excellent through-hardening properties
- Good dimensional stability during hardening

Typical analysis %	C 0.39	Si 1.0	Mn 0.4	Cr 5.2	Mo 1.4	V 0.9
Standard specification	Superior AISI H13					
Delivery condition	Soft annealed to approx. 180 HB					
Color code	Blue/grey					

IMPROVED TOOLING PERFORMANCE

The name "SUPERIOR" indicates that by utilizing special processing techniques and close control, the steel has attained high purity and a very fine structure. Further, Orvar Superior shows significant improvements in isotropic properties compared to conventionally produced AISI H13 grades.

These improved isotropic properties are particularly valuable for tooling subjected to high mechanical and thermal fatigue stresses, e.g. die casting dies, forging tools and extrusion tooling. In practical terms, tools may be used at somewhat higher working hardnesses (+1 to 2 HRC) without loss of toughness. Since increased hardness slows down the formation of heat checking cracks, improved tool performance can be expected.

Orvar Superior has been specially designed to meet the North American Die Casting Association (NADCA) #207-2003 specification for superior high quality H-13 die steel.

Applications

TOOLS FOR DIE CASTING

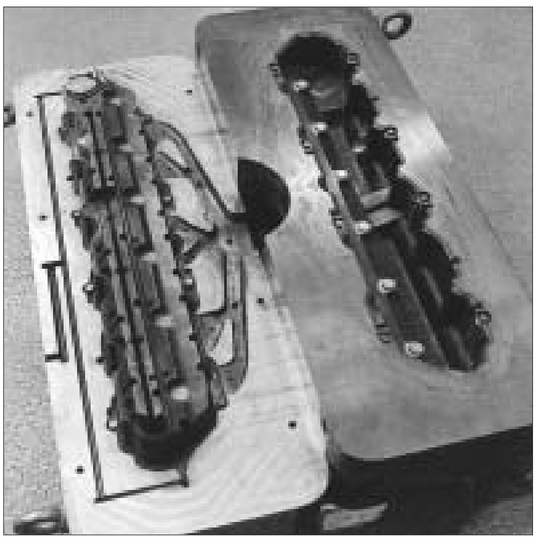
Part	Tin, lead zinc alloys HRC	Aluminum, magnesium alloys, HRC	Copper alloys HRC
Dies	46–50	42–48	(QRO 90 S)
Fixed inserts cores	46–52	44–48	(QRO 90 S)
Sprue parts	48–52	46–48	(QRO 90 S)
Nozzles	35–42	42–48	(QRO 90 S)
Ejector pins (nitrided)	46–50	46–50	46–50
Plunger, shot-sleeve (normally nitrided)	42–46	42–48	(QRO 90 S)
Austenitizing temperature	1870–1885°F (1020–1030°C)		1900–1920°F (1040–1050°C)

TOOLS FOR EXTRUSION

Part	Aluminum, magnesium alloys, HRC	Copper alloys HRC	Stainless steel HRC
Dies	44–50	43–47	45–50
Backers, die-holders, liners, dummy blocks, stems	41–50	40–48	40–48
Austenitizing temperature (approx.)	1870–1885°F (1020–1030°C)	1900–1920°F (1040–1050°C)	

TOOLS FOR FORGING

Material	Aust. temp. (approx.)	HRC
Aluminum, magnesium	1870–1885°F (1020–1030°C)	44–52
Copper alloys	1900–1920°F (1040–1050°C)	44–52
Steel	1900–1920°F (1040–1050°C)	40–50



MOLDS FOR PLASTICS

Part	Austenitizing temp.	HRC
Injection molds Compression/ transfer molds	1870–1885°F (1020–1030°C) Tempering 480°F (250°C)	50–52

OTHER APPLICATIONS

Application	Austenitizing temp.	HRC
Severe cold punching, scrap shears	1870–1885°F (1020–1030°C) Tempering 480°F (250°C)	50–52
Hot shearing	1870–1885°F (1020–1030°C) Tempering 1. 480°F (250°C) or 2. 1070–1110°F (575–600°C)	50–52 45–50
Shrink rings (e.g. for cemented carbide dies)	1870–1885°F (1020–1030°C) Tempering 1070–1110°F (575–600°C)	45–50
Wear-resisting parts	1870–1885°F (1020–1030°C) Tempering 1070°F (575°C) Nitriding	Core 50–52 Surface ~1000HV$_1$

Properties

Unless indicated all specimens were taken from the center of a 16" x 5" (407 x 127 mm) bar, heated for 30 minutes at 1875°F (1025°C), quenched in air and tempered 2 + 2 h at 1130°F (610°C) to a hardness of 45 ± 1 HRC.

PHYSICAL DATA

Data at room and elevated temperatures.

Temperature	(68°F) 20°C	(750°F) 400°C	(1110°F) 600°C
Density lbs/in^3 kg/m^3	 0.281 7 800	 0.277 7 700	 0.274 7 600
Modulus of elasticity psi MPa	 30.5 x 10^6 210 000	 26.1 x 10^6 180 000	 20.3 x 10^6 140 000
Coefficient of thermal expansion per °F from 68°F °C from 20°C	 – –	 7.0 x 10^{-6} 12.6 x 10^{-6}	 7.3 x 10^{-6} 13.2 x 10^{-6}
Thermal conductivity Btu in/(ft^{2}h°F) W/m °C	 176 25	 204 29	 211 30

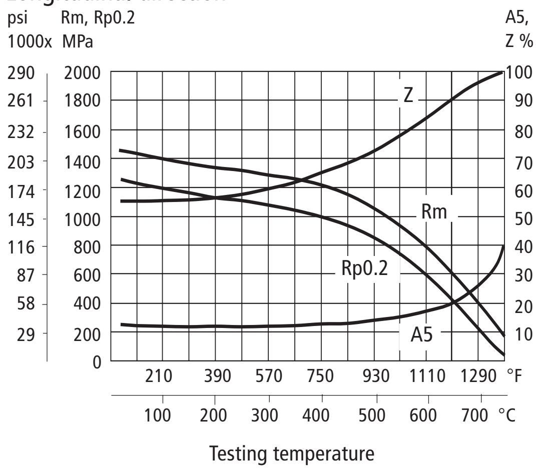
MECHANICAL PROPERTIES

Approximate tensile strength at room temperature.

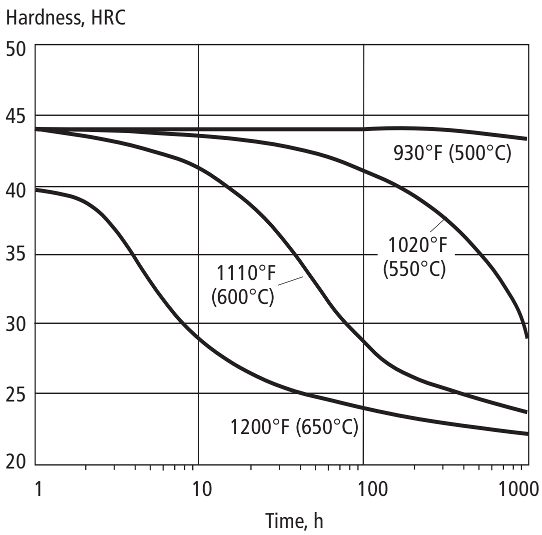
Hardness	52 HRC	45 HRC
Tensile strength Rm	263 000 psi 117 tsi 1820 MPa 185 kp/mm^2	206 000 psi 92 tsi 1420 MPa 145 kp/mm^2
Yield strength Rp0.2	220 000 psi 98 tsi 1520 MPa 155 kp/mm^2	185 000 psi 83 tsi 1280 MPa 130 kp/mm^2

Approximate strength at elevated temperatures

Longitudinal direction.

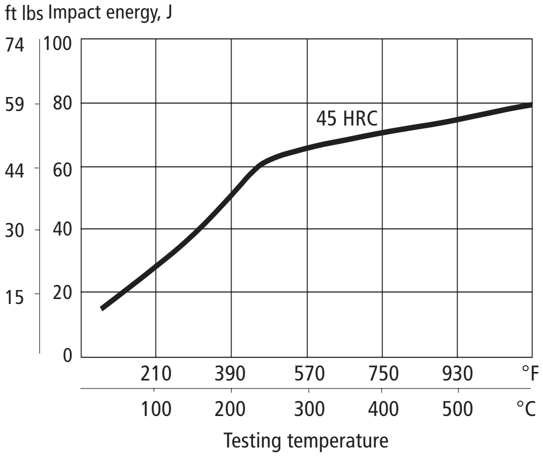


Effect of time at high temperatures on hardness



Effect of testing temperature on impact energy

Charpy V specimens, short transverse direction.



QUENCHING MEDIA

- High speed gas/circulating atmosphere
- Vacuum (high speed gas with sufficient positive pressure). An interrupted quench is recommended where distortion control and quench cracking are a concern
- Martempering bath or fluidized bed at 840–1020°F (450–550°C), then cool in air
- Martempering bath or fluidized bed at approx. 360–430°F (180–220°C) then cool in air
- Warm oil

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

Heat treatment–general recommendations

SOFT ANNEALING

Protect the steel and heat through to 1560°F (850°C). Then cool in the furnace at 20°F (10°C) per hour to 1200°F (650°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: 1110–1560°F (600–850°C), normally in two pre-heating steps.

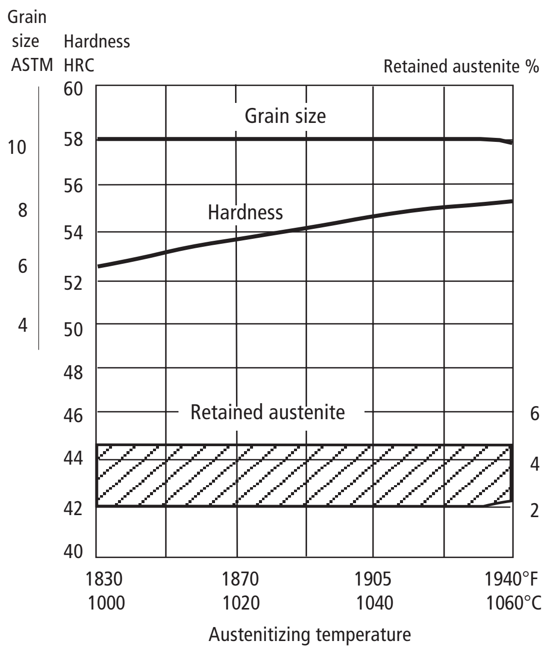
Austenitizing temperature: 1870–1920°F (1020–1050°C), normally 1870–1885°F (1020–1030°C).

Temperature °F	°C	Soaking* time minutes	Hardness before tempering
1875	1025	30	53±2 HRC
1920	1050	15	54±2 HRC

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

Protect the part against decarburization and oxidation during hardening.

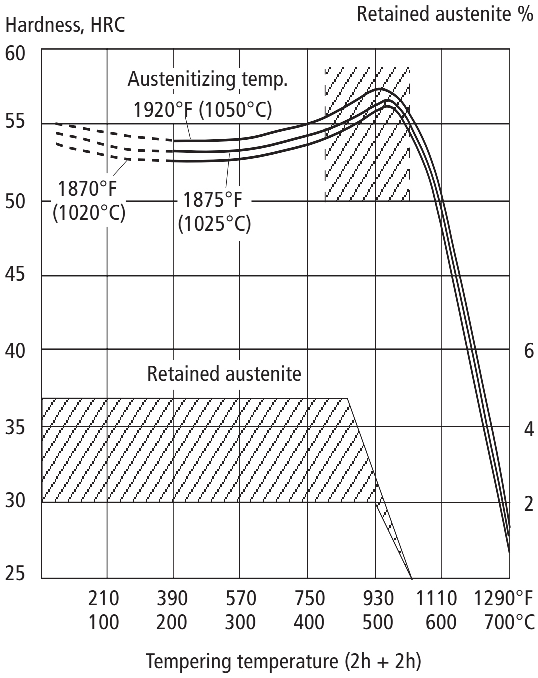
Hardness, grain size and retained austenite as functions of austenitizing temperature



TEMPERING

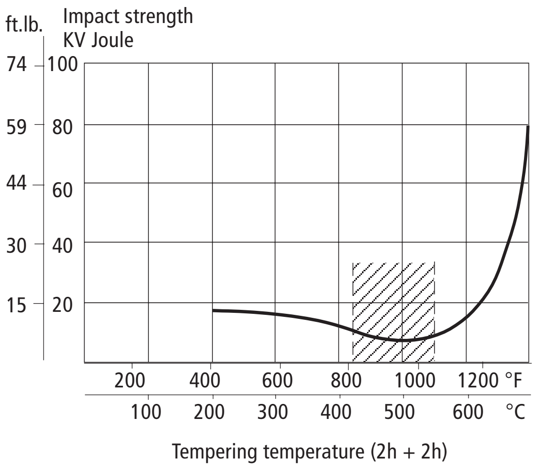
Choose the tempering temperature according to the hardness required by referencing the tempering graph below. Temper minimum twice with intermediate cooling to room temperature. Lowest tempering temperature 480°F (250°C). Holding time at temperature minimum 2 hours. To avoid "temper brittleness", do not temper in the range 800–1020°F (425–550°C), see graph.

Tempering graph



Approximate impact strength at different tempering temperatures.

Charpy V specimens, short transverse direction.



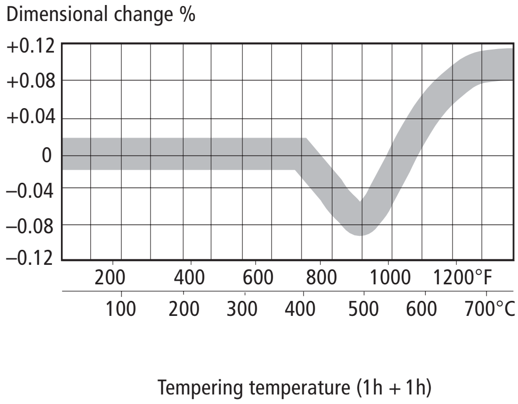
Tempering within the range 800–1020°F (425–550°C) is normally not recommended due to the reduction in toughness properties.

DIMENSIONAL CHANGES DURING HARDENING

Sample plate. 4" x 4" x 1", 100 x 100 x 25 mm.

		Width %	Length %	Thickness %
Oil hardened from 1870°F (1020°C)	Min.	–0.08	–0.06	±0
	Max.	–0.15	–0.16	+0.30
Air hardened from 1870°F (1020°C)	Min.	–0.02	–0.05	±0
	Max.	+0.03	+0.02	+0.05
Vac hardened from 1870°F (1020°C)	Min.	+0.01	–0.02	+0.08
	Max.	+0.02	–0.04	+0.12

DIMENSIONAL CHANGES DURING TEMPERING



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

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 flake when exposed to mechanical or thermal shock, the risk increasing with layer thickness. Before nitriding, the tool should be hardened and tempered at a temperature at least 45–90°F (25–50°C) above the nitriding temperature.

Nitriding in ammonia gas at 950°F (510°C) or plasma nitriding in a 75% hydrogen/25% nitrogen mixture at 895°F (480°C) both result in a surface hardness of about 1100 $HV_{0.2}$. In general, plasma nitriding is the preferred method because of better control over nitrogen potential; in particular, formation of the so-called white layer, which is not recommended for hot-work service, can readily be avoided. However, careful gas nitriding can give perfectly acceptable results.

Orvar Superior can also be nitrocarburized in either gas or salt bath. The surface hardness after nitrocarburizing is 900–1000 $HV_{0.2}$.

DEPTH OF NITRIDING

Process	Time	Depth inch	Depth mm
Gas nitriding at 950°F (510°C)	10 h 30 h	0.0047 0.0079	0.12 0.20
Plasma nitriding at 895°F (480°C)	10 h 30 h	0.0047 0.0071	0.12 0.18
Nitrocarburizing – in gas at 1075°F (580°C)	2.5 h	0.0043	0.11
– in salt bath at 1075°F (580°C)	1 h	0.0024	0.06

Nitriding to case depths >0.012 inch (>0.3 mm) is not recommended for hot-work applications. Orvar Superior can be nitrided in the soft-annealed condition. The hardness and depth of case will, however, be reduced somewhat in this case.

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 high speed steel: Fine turning
Cutting speed (v_c) f.p.m.	660–820	820–985	82–100
m/min	200–250	250–300	25–30
Feed (f) i.p.r.	0.008–0.016	0.002–0.008	0.002–0.012
mm/r	0.2–0.4	0.05–0.2	0.05–0.3
Depth of cut (a_p) inch	0.08–0.16	0.02–0.08	0.02–0.08
mm	2–4	0.5–2	0.5–2
Carbide designation US	C5–C6	C7	–
ISO	P20–P30 Coated carbide	P10 Coated carbide or cermet	–

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	52–59*	16–18*	0.002–0.006	0.05–0.15
3/16–3/8	5–10	52–59*	16–18*	0.006–0.008	0.15–0.20
3/8–5/8	10–15	52–59*	16–18*	0.008–0.010	0.20–0.25
5/8–3/4	15–20	52–59*	16–18*	0.010–0.014	0.25–0.35

* *For coated HSS drill v_c = 92–98 f.p.m. (28–30 m/min.).*

Carbide drill

Cutting data parameters	Type of drill: Indexable insert	Solid carbide	Brazed carbide[1]
Cutting speed (v_c) f.p.m.	720–785	425–525	260–360
m/min	220–240	130–160	80–110
Feed (f) i.p.r.	0.001–0.004[2]	0.004–0.010[2]	0.006–0.010[2]
mm/r	0.03–0.10[2]	0.10–0.25[2]	0.15–0.25[2]

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

MILLING

Face milling and square shoulder face milling

Cutting data parameters	Milling with carbide: Rough milling	Milling with carbide: Fine milling
Cutting speed (v_c) f.p.m.	590–850	850–985
m/min	180–260	260–300
Feed (f_z) inch/tooth	0.008–0.016	0.004–0.008
mm/tooth	0.2–0.4	0.1–0.2
Depth of cut (a_p) inch	0.08–0.20	–0.08
mm	2–5	–2
Carbide designation US	C5–C6	C6–C7
ISO	P20–P40 Coated carbide	P10–P20 Coated carbide or cermet

End milling

Cutting data parameters	Type of end mill: Solid carbide	Carbide indexable insert	High speed steel
Cutting speed (v_c) f.p.m.	525–660	560–755	115–130[1]
m/min	160–200	170–230	35–40[1]
Feed (f_z) inch/tooth	0.001–0.008[2]	0.003–0.008[2]	0.002–0.014[2]
mm/tooth	0.03–0.20[2]	0.08–0.20[2]	0.05–0.35[2]
Carbide designation US		C5, C6	
ISO	–	P20, P30	–

[1] For coated HSS end mill v_c 180–195 f.p.m. (55–60 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 brochure "Grinding of Tool Steel" and can also be obtained from the grinding wheel manufacturer.

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 KV

Welding

Welding of tool steel can be performed with good results if proper precautions are taken regarding elevated temperature, joint preparation, choice of consumables and welding procedure.

Welding method	TIG	MMA
Working temperature	620–710°F 325–375°C	620–710°F 325–375°C
Filler metal	QRO 90 TIG-WELD DIEVAR TIG-WELD	QRO 90 WELD
Hardness after welding	50–55 HRC	50–55 HRC
Heat treatment after welding		
Hardened condition	Temper at 45°F (25°C) below the original tempering temperature.	
Soft annealed condition	Soft-anneal the material at 1560°F (850°C) in protected atmosphere. Then cool in the furnace at 20°F (10°C) per hour to 1200°F (650°C) then freely in air.	

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

Electrical-discharge machining

If spark-erosion 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. 50°F (25°C) below the previous tempering temperature.

Hard-chromium plating

After plating, parts should be tempered at 360°F (180°C) for 4 hours within 4 hours of plating to avoid the risk of hydrogen embrittlement.

Texturing

Orvar Superior is particularly suitable for texturing by the photo-etching method. Its high level of homogeneity and low sulfur content ensures accurate and consistent pattern reproduction.

Polishing

Orvar Superior exhibits good polishability in the hardened and tempered condition. Polishing after grinding can be effected using aluminum oxide or diamond paste.

Typical procedure:

1. Rough grinding to 180–320 grain size using a wheel or stone.
2. Fine grinding with abrasive paper or powder down to 400–800 grain size.
3. Polish with diamond paste grade 15 (15µm grain size) using a polishing tool of soft wood or fiber.
4. Polish with diamond paste 3 (3µm grain size) using a polishing tool of soft wood or fiber.
5. When demands on surface finish are high, grade 1 (1µm grain size) diamond paste can be used for final polishing with a fiber polishing pad.

Further information

Please contact Bohler-Uddeholm for further information on the selection, heat treatment, application and availability of Uddeholm tool steels.

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Edition: 1, 04.2004