sij | ravne steel

HOT WORK TOOL STEEL

RAVNEX

RS 440

Family of RS hot-work tool steel

HOT WORK TOOL STEEL

GRADE RS		W. Nr.	DIN	AISI
RS 400		1.2343	X38CrMoV5-1	H11
RS 410		1.2344	X40CrMoV5-1	H13
RS 420		1.2367	X38CrMoV5-3	-
RS 431		1.2345	X50CrMoV5-1	-
RS 432		1.2362	X63CrMoV5-1	-
RS 433		1.2365	X32CrMoV33	H10
RS 435		1.2714	56NiCrMoV7	-
RS 440	RAVNEX	1.2343 Mod.	X38CrMoV5-1 Mod.	H11 Mod.
RS 450	RAVNEX		-	-

RAVNEX RS 440

CONTENTS

GENERAL CHARACTERISTICS

NOTES

RS 440 RAVNEX is a supreme hot-work tool steel produced in METAL RAVNE, known for:

- High impact toughness
- High hot tensile properties and high working hardness
- High thermal conductivity
- Good polishability
- Nitrability
- High cleanliness
- Longer tool life
- Excellent homogeneity
- Weldability

RS CHEMICAL COMPOSITION (%)

Controlled chemical composition with minimal content of detrimental elements compared to standard steel grades. Cleanliness according to DIN 50602 is K1≤10.

RS GRADE	AISI	W. Nr.	C	Si	Mn	Cr	Mo	V
RS 440 RAVNEX	H11 mod	~1.2343	0.36	0.20	0.30	5.00	1.35	0.45

Chemical element content is in wt.%

RS ANWENDUNG

RS 440 RAVNEX is primarily designed for die casting of light metals and alloys. It is often used for highly stressed hot-work structural parts where superior toughness is required (up to average Charpy V-notch value of 29.8 Joule at 44-46 HRC according to NADCA#207).

RS 440 RAVNEX is also recommended for die forging and extrusion. Because of its good polishability, the grade can be used for plastic molding applications and processing of glass.

RS 440 RAVNEX is supplied in annealed condition, max. 209 HBW (705 N/mm²).

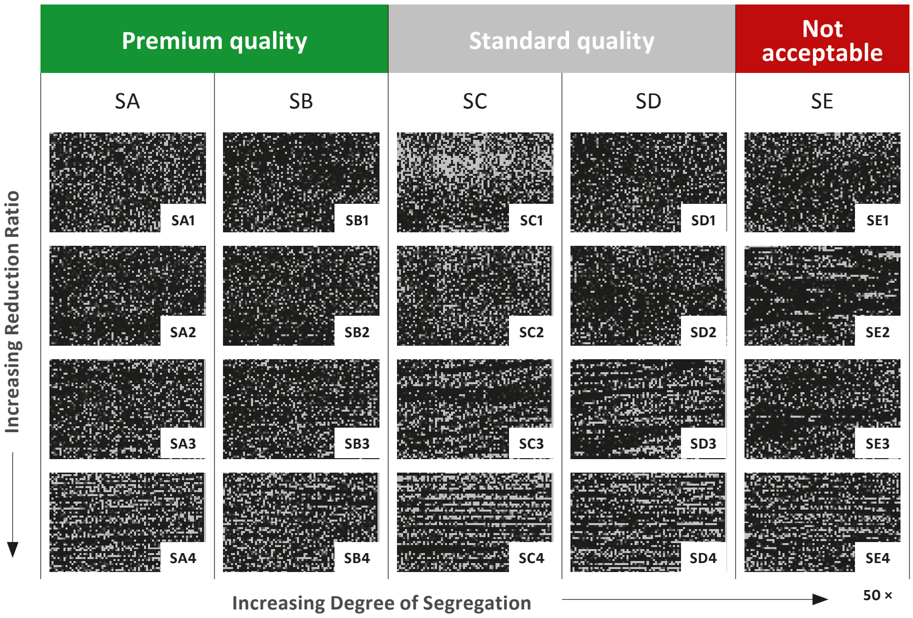
NOTES

GENERAL CHARACTERISTICS

MICROSTRUCTURE IN DELIVERED CONDITION

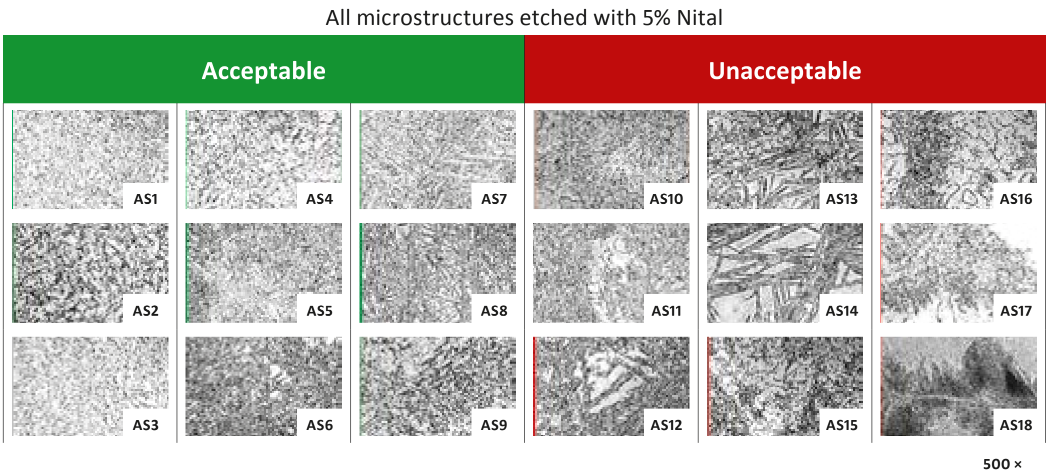
RS 440 RAVNEX is inspected in soft annealed condition according to SEP 1614 (Stahl-Eisen-Prüfblatt SEP 1614 - September 1996), and according to NADCA#207 standard.

TAB 1: MICROHOMOGENEITY



Accepted rating charts of annealed **RS 440 RAVNEX.**

TAB 2: ACCEPTABILITY CRITERIA OF ANNEALED MICROSTRUCTURE ACCORDING TO NADCA #207-2003

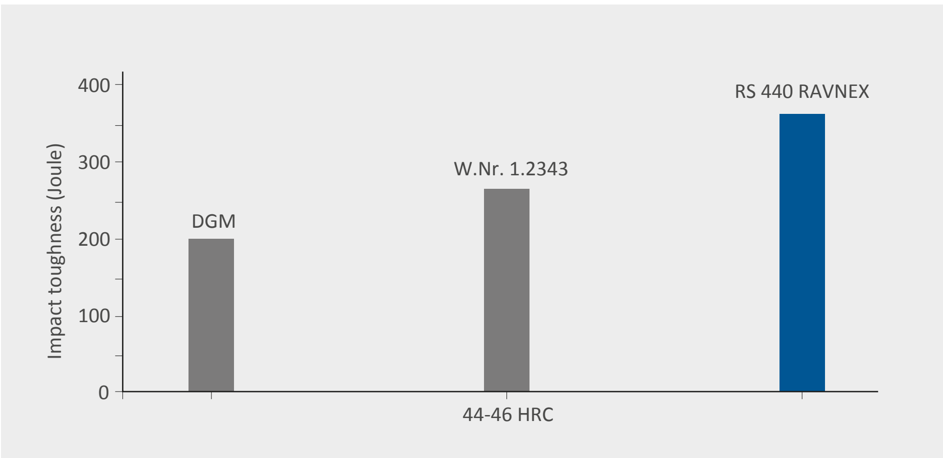


NOTES

GENERAL CHARACTERISTICS

TOUGHNESS

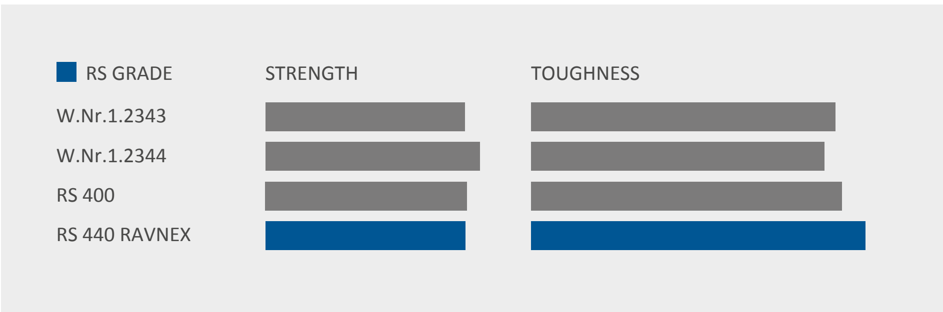
Un-notched specimens (7 × 10 × 55 mm³) are used to test impact toughness in transverse direction, SEP 1314 (Stahl-Eisen-Prüfblatt SEP 1314- April 1990). Specimens are quenched and tempered to 45 +/- 2 HRC, and test is performed at 20˚C.
Average impact toughness of forged quality is higher than 299 Joule for average forging size of 900 × 400 mm.



DGM (Deutsche Gesellschaft für Materialkunde) recommends impact toughness of minimum 200 Joules for hot-work tool steel in various hot-work applications.

QUALITATIVE COMPARISON

RS 440 RAVNEX is a premium tool steel of highest toughness produced in Metal Ravne. Chart shows its toughness at high temperature compared to RS400 and conventional W.Nr1.2344 hot-work tool steel. Tool steel with increased toughness at high temperature is critical in applications where there is risk of gross cracking. Properties are measured at 600 °C.



STRENGTH means ultimate tensile strength derived from an engineering stress-strain curve.

TOUGHNESS is estimated by reduction in cross-section area of tensile test probe at rupture.

PHYSICAL PROPERTIES

NOTES

PHYSICAL PROPERTIES (TEMPERATURE DEPENDENTS)

DENSITY (g/cm³)

7.85 (20 °C)	7.80 (450 °C)	7.69 (500 °C)	7.67 (550 °C)	7.65 (600 °C)

THERMAL CONDUCTIVITY (W/(m.K))

28.4 (100 °C)	30.1 (450 °C)	30 (500 °C)	29.90 (550 °C)	29.70 (600 °C)

ELECTRIC RESISTIVITY (Ohm. mm²/m)

0.50 (20 °C)	0.68 (450 °C)	0.86 (500 °C)	0.90 (550 °C)	0.96 (600 °C)

SPECIFIC HEAT CAPACITY (J/(g.K))

0.46 (20 °C)	0.51 (450 °C)	0.55 (500 °C)	0.57 (550 °C)	0.59 (600 °C)

MODULUS OF ELASTICITY ($10^3 \times N/mm^2$)

215 (20 °C)	185 (450 °C)	176 (500 °C)	171 (550 °C)	165 (600 °C)

COEFFICIENT OF LINEAR THERMAL EXPANSION (10^{-6} °C $^{-1}$, 20 °C)*

12.40 (200 °C)	12.80 (300 °C)	13.20 (400 °C)	13.60 (500°C)	14.20 (600 °C)

* CTE is the mean coefficient of thermal expansion with reference temperature of 20 °C.

MECHANICAL PROPERTIES

NOTES

IMPACT TOUGHNESS AT ELEVATED TEMPERATURES

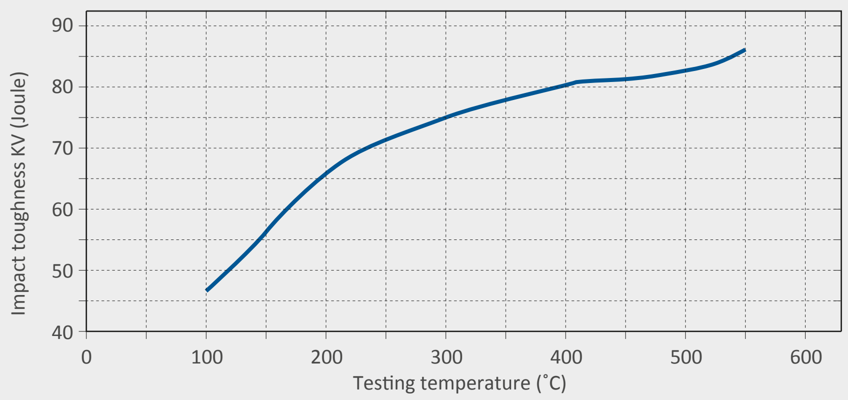
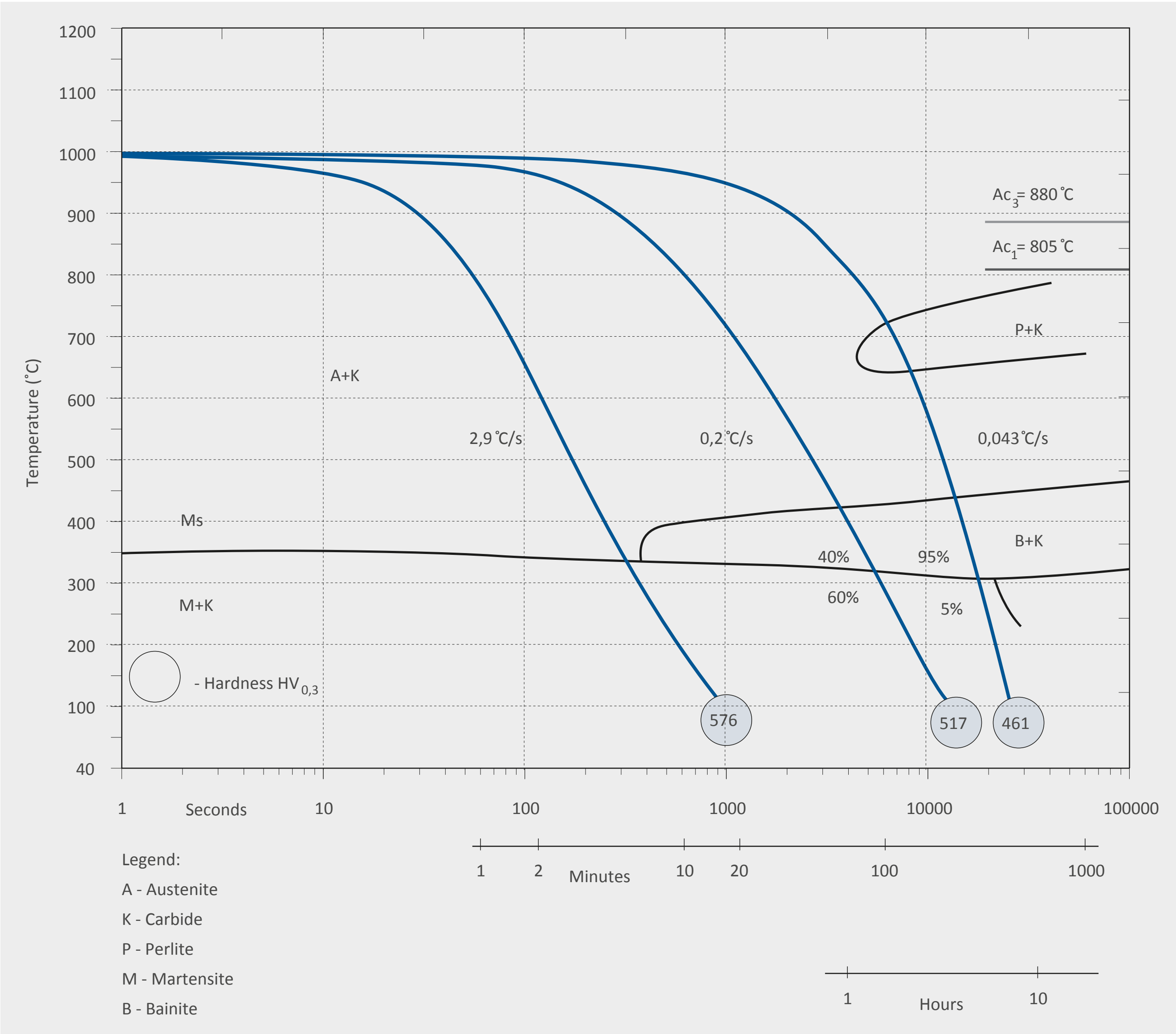


Figure shows impact toughness as function of temperature. Samples are taken from the core of a forged block in short transverse direction. They are quenched and tempered (Q+T; 1000 °C / oil / 2x tempering) to 45 +/- 1 HRC. Measurement: EN ISO 148: 2010

CONTINIOUS COOLING CURVES-CCT

NOTES

Austenitising temperature: 990 °C; soak time: 15 min



TIP 1 → **Quench rate should be sufficient to form predominantly martensitic structure without significant amount of bainite. Significant amount of bainite favours thermal fatigue as a less stable phase constituent with lower strength.**

HEAT TREATMENT

NOTES

Recommendations or NADCA#207.

ANNEALING

HEATING	ANNEALING TEMPERATURE	COOLING
50 °C/h	800 - 850 °C	20 °C/h
Protect against oxidation, scaling and decarburisation.	Min. 4 hours.	Slow in furnace. From 600 °C air cooling is possible.

STRESS RELIEVING

HEATING	STRESS RELIEVING	COOLING
100°C/h	600 - 650 °C or 50 °C under the last tempering temperature.	20°C/h
Protect against oxidation and decarburisation.	Min. 3 hours.	Slow and uniformly in the furnace to prevent formation of additional residual stresses. From approximately 200 °C air cooling is possible.

HARDENING

Hardness after hardening is 50-54 HRC (1680 - 1916 N/mm²).

HEATING	AUSTENITISING	COOLING
25 - 650 °C, 150-220 °C/h 650 - 850 °C, ≤150 °C/h 850 - 1000 °C, ≤150 °C/h	1000 -1020 °C	See CCT diagram
Hold in furnace at T = 650 °C / 850°C until $T_{SURFACE}$-T_{CORE} ≤ 110 °C / 60 °C.	$T_{SURFACE}$ is measured at 15mm underneath surface, maximum soak time is 30 min.	Fast cooling is recommended in pressurized N_2. For large dimension hot-work tooling see NADCA#207 or GM DC-9999-1Rev.18 specification.

TIP 2

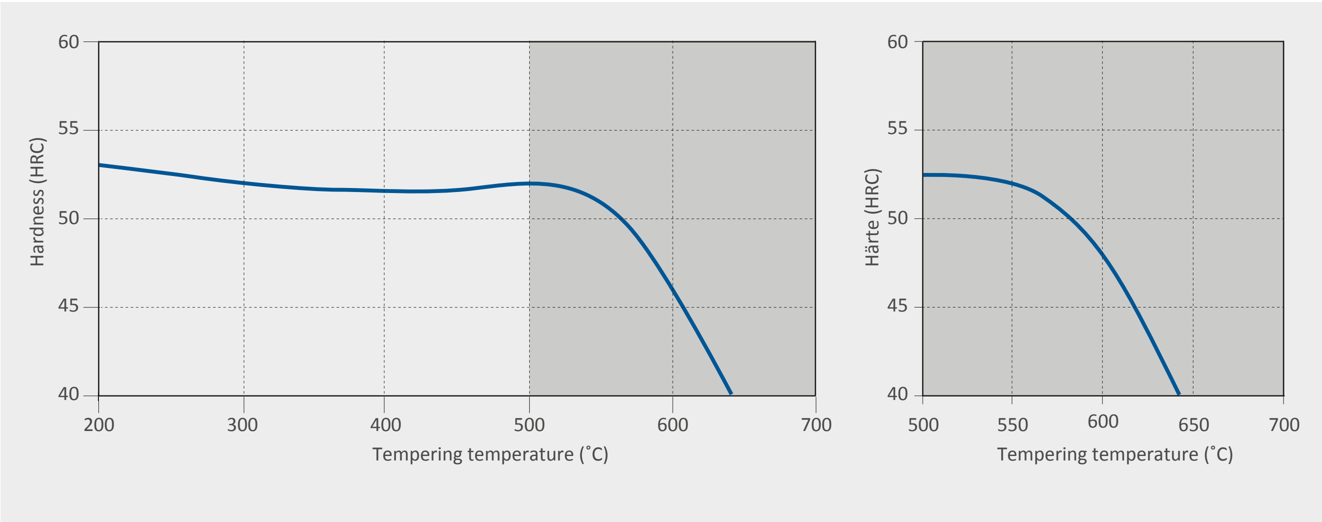
→ **For applications exposed to extreme thermal loading a proper heat treatment is essential. To prevent excessive grain growth during austenitization it is preferable to leave some of the carbides not dissolved.**

HEAT TREATMENT

TEMPERING

Tempering must start immediately after completion of quenching (when part reaches 90-70 ˚C).
Three tempering treatments are recommended. First tempering destabilizes retained austenite.
Second tempering tempers newly formed microstructure constituents.

HEATING	TEMPERING TEMPERTAURE	COOLING
150 °C/h – 250 °C/h	1st: 520-530 °C 2nd: choose working hardness (see tempering diagram). 3rd: 50 °C bellow 2nd tempering.	Cool in air or in the furnace to room temperature between tempering cycles.
Protect against oxidation and decarburisation.	1 hour per 25mm wall thickness based on the furnace temperature. Minimum 2 hours.	



TIP 3 → **Increased toughness of this special grade offers one to select higher working hardness. Higher thermal conductivity and high temperature strength compared to H11 grade also contribute to its improved resistance to thermal fatigue.**

DIMENSIONAL CHANGES DURING HARDENING AND TEMPERING

It is recommended to leave machining allowance before hardening of minimum 0.2 % of dimension, equal in all three directions.

SURFACE TREATMENT

NITRIDING AND NITROCARBURISING

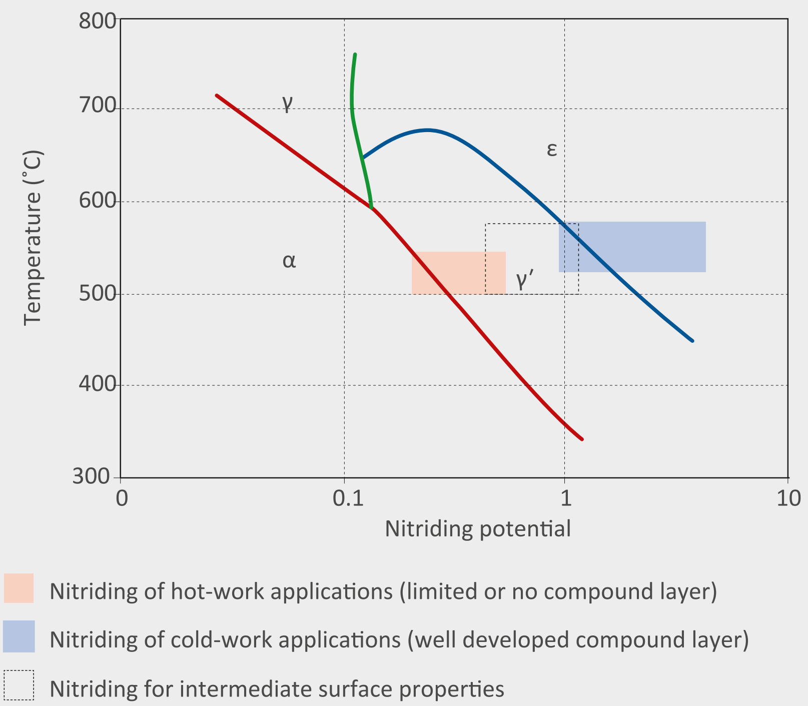
Nitriding treatment is commonly recommended to enhance surface properties of **RS440 RAVNEX.**

Nitriding treatment for hot-work applications is performed by producing diffusion zone only (α nitriding phase) of a depth determined by particular application requirements, and completely inhibit surface compound layer (γ' and ε nitriding phases).

Nitriding treatment for plastic-molding or cold-work applications with wear resistance requirements is performed by producing surface compound layer of composition and thickness determined by particular application requirements.

For applications with requirement for additional surface protection, improvement of sliding properties, or improvement of corrosion resistance, it is recommended that oxidation treatment (Fe_3O_4) follows the nitriding.

For details on surface preparation and setup of nitriding treatment parameters to obtain required surface properties please consult our approved nitriding specialist.



Lehrer diagram presented in figure shows the effect of two parameters: (1) nitriding potential (a function of partial pressure of ammonia and hydrogen), and (2) temperature, on composition of nitriding phases formed on material surface. Figure shows recommended selection of the two governing parameters for appropriate execution of nitriding for two extreme application regimes, hot work on one hand, and cold-work on the other.

WELDING AND EDM

NOTES

WELDING

RS 440 RAVNEX is a readily weldable alloy by TIG or MMA welding processes in hardened or soft-annealed condition. Filler metal should be of the same or similar chemical composition.

Heat treatment after welding is recommended. Annealing should be performed after welding of soft annealed parts, whereas tempering at temperature of about 50˚C below tempering temperature should be performed after welding of hardened and tempered parts. Laser welding is recommended for repair of smaller cracks and edges.

PREHEATING TEMPERATURE	MAXIMUM INTERPASS TEMPERATURE	POST WELD COOLING
320 - 350 °C	470 °C	Approximately 30 °C / h to not less than 70 °C, then tempering.

WELDING METHOD	FILLER MATERIAL	HARDNESS AFTER WELDING
TIG, MMA	H11	~ 50 HRC

ELECTRICAL DISCHARGE MACHINING

Electrical discharge machining (EDM) leaves a brittle surface layer due to melting and resolidification of surface material.

It is recommended to: (1) remove the resolidified layer by polishing, grinding or other mechanical methods, and (2) temper the work-piece at temperature of about 50 °C below the tempering temperature. Execution of tempering of re-hardened and jet untempered layer underneath the surface is critical.

RECOMENDATIONS FOR MACHINING

NOTES

The information below is provided solely as a general machining guideline.
It refers to material soft annealed condition.

DRILLING

INSERT	DRILL DIAMETER (mm)	CUT TING SPEED (m/min)	FEED (mm/rev)
HSS	5 - 20	15 - 20	0.05 - 0.30
Coated HSS	5 - 20	35 - 40	0.05 - 0.30

FACE MILLING

INSERT	CUT TING SPEED (m/min)	FEED (mm/tooth)	DEPTH OF CUT (mm)
P20-P40 c.* (rough milling)	150 - 220	0.20 - 0.40	2.00 - 4.00
P10 c.* (fine milling)	230 - 260	0.10 - 0.20	- 2.00

TURNING

INSERT	CUT TING SPEED (m/min)	FEED (mm/rev)	DEPTH OF CUT (mm)
P20-P30 c.* (rough turning)	180 - 220	0.20 - 0.40	2.00 - 4.00
P10 c.* (fine turning)	230 - 270	0.05 - 0.20	0.50 - 2.00
HSS (fine turning)	25 - 30	- 0.30	- 2.00

* c. = coated carbide

HEAT TREATMENT OF RS 440 RAVNEX

Control of quenching is critical to assure dimension stability, optimum microstructure and mechanical properties of any work-piece. Finite element modelling of heat treatment reveals that both hardening temperature and soaking time, as well as quenching rate strongly depend on work piece size and geometry.

FIG 1

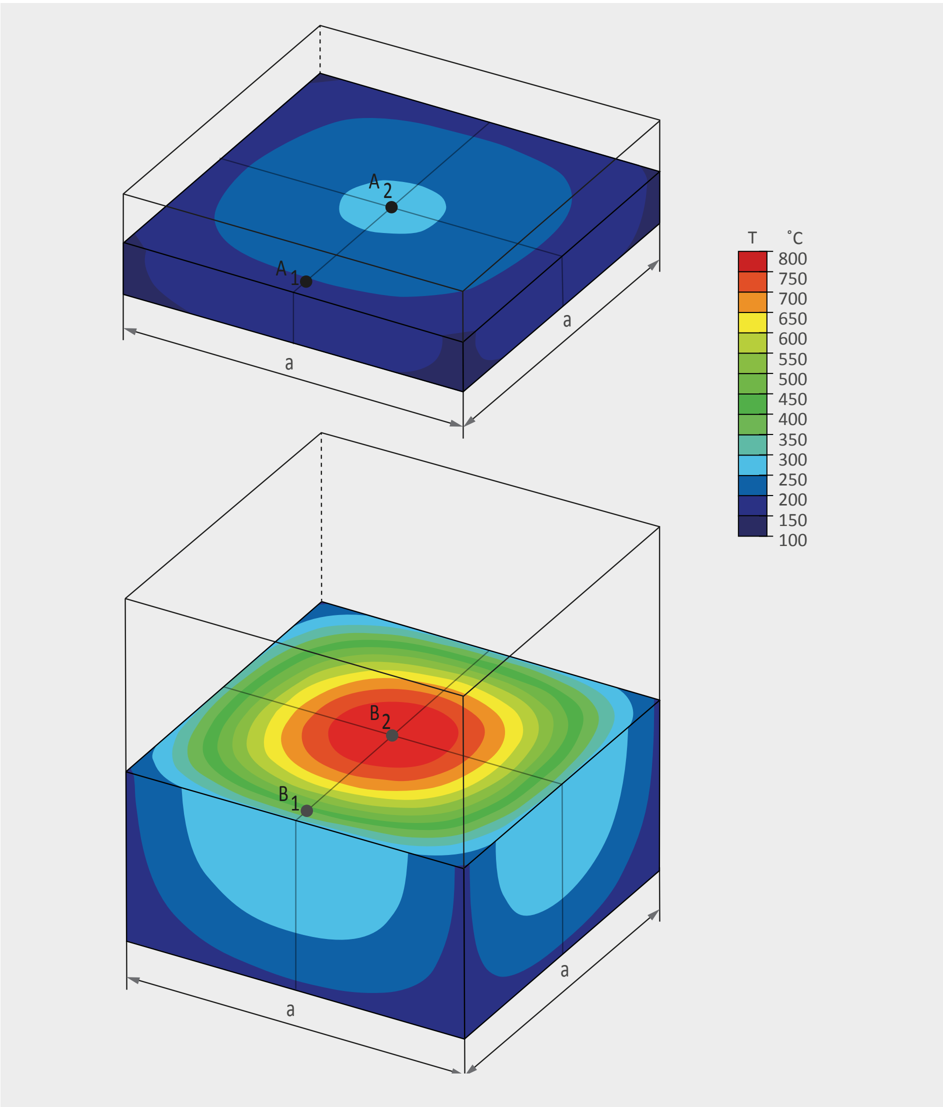
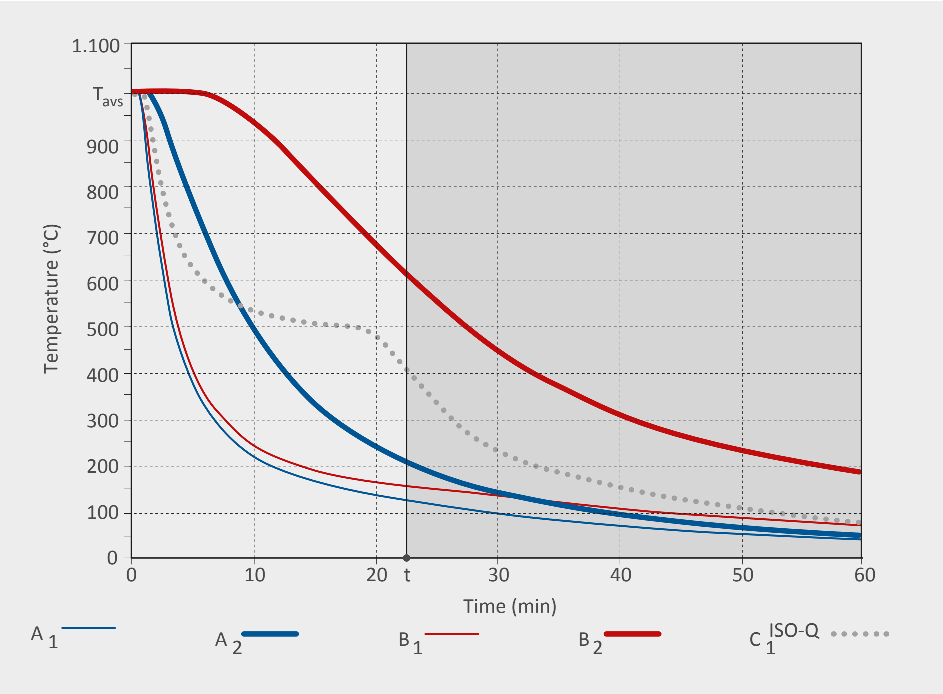


Figure 1 shows temperature distribution in two workpieces of different thickness at **a given time (t),** (see Figure 2) during quenching. One can observe a hot core and a high temperature gradient in a thick workpiece, while a thin workpiece has at same cooling time almost uniform temperature distribution.

CASE STUDY

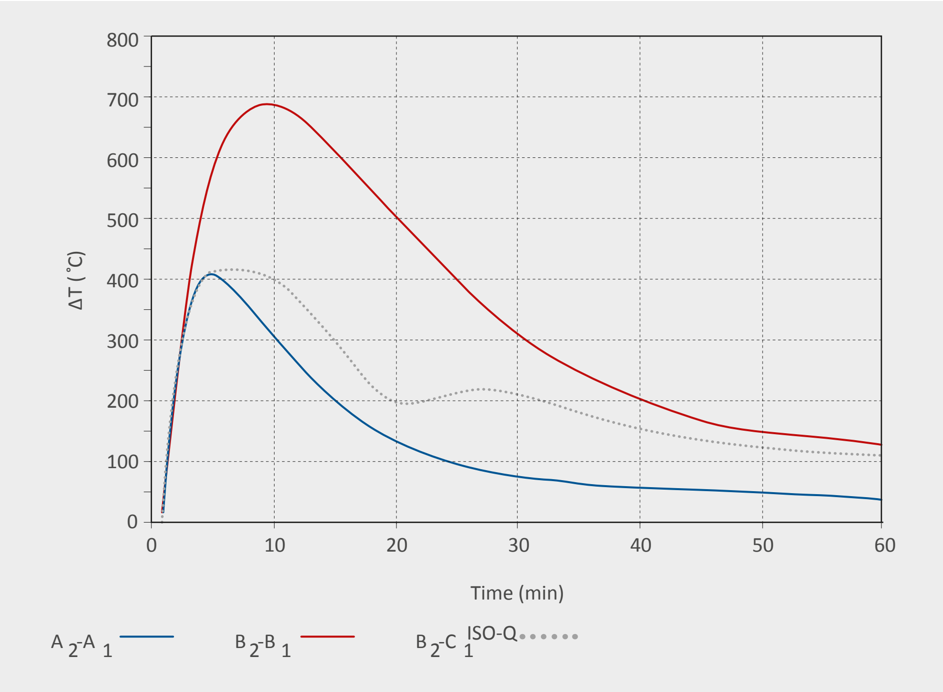
NOTES

→ FIG 2



← Figure 2 reveals temperature transient at quenching for both workpieces at two characteristic points: (1) a point 15mm underneath the surface, and (2) the core.

→ FIG 3



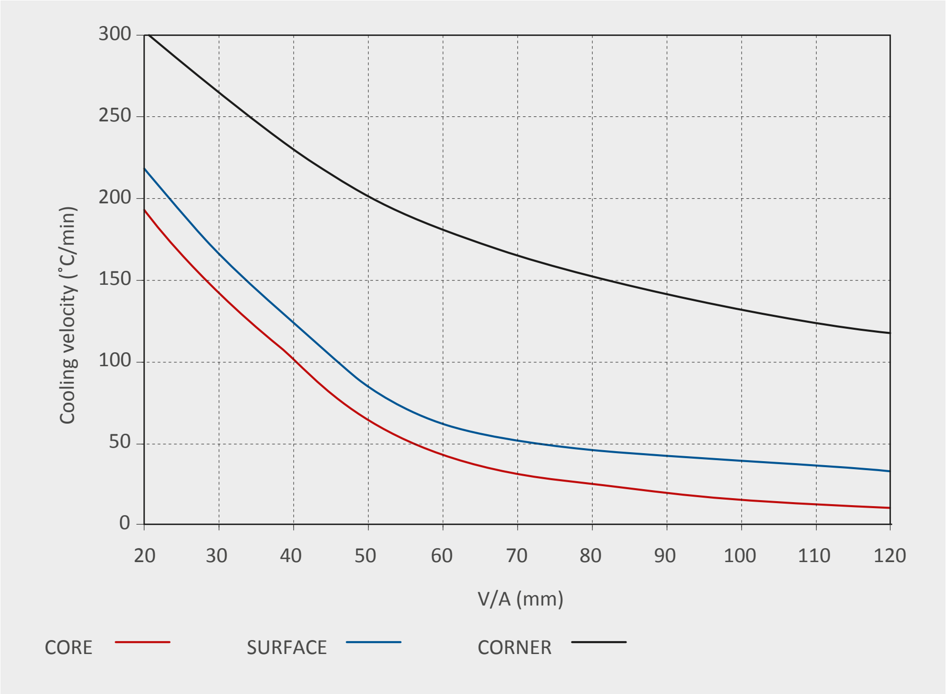
← Figure 3 shows temperature difference between the two characteristic points for both workpieces for the same quenching transient. An extreme temperature gradient occurs in the thick workpiece, with high risk of causing distortion or gross cracking. Application of isothermal quenching process (see NADCA#207) is recommended to reduce the potential detrimental effects of extreme temperature difference. A short isothermal hold reduces significantly the temperature gradient in the thick workpiece. (See surface temperature transifnt curve C1ISO-Q in Figure 2 and Figure 3.)

CASE STUDY

To achieve optimum material properties, heat treatment parameters should be adjusted to specific workpiece size and geometry. Critical quench rate is needed to avoid both pearlite formation and carbide precipitation.

In order to run quenching of a particular dimension and geometry workpiece at optimum velocity it is critical to continuously monitor temperature of both the surface and the core throughout the cycle.

→ **ABB.4**



← Figure 4 shows average cooling speed between 800 and 500°C at the core of a generalized geometry workpiece. Both geometry and size of the workpiece is defined by its volume (V) to surface (S) ratio. Medium quenching power in a vacuum-type furnace is applied to determine the workpiece cooling speed (6bar N2 overpressure with medium to high gas circulation). The plot is particularly useful for determining optimum quenching speed in workpieces where temperature at core is not possible to directly monitor by thermocouple.

SURFACE – temperature at a point 15 mm underneath the center of largest workpiece surface.

CORNER* – temperature at a point 15 mm underneath the most exposed part of workpiece.

* data presented are computed for a point 15mm underneath an angle of a cube.

TIP 4 → **Sharp edges on the tool in heat treatment should be avoided to prevent gross cracking or micro quenching cracks which can lead to formation of leading cracks.**

www.rsc.si

RS 440 RAVNEX is produced by:

Metal Ravne d.o.o.
Koroška cesta 14
2390 Ravne na Koroškem
Slovenia

www.metalravne.com

RS 440 RAVNEX is distributed by:

Ravne Steel Center d.o.o.
Litostrojska cesta 60
1000 Ljubljana
Slovenia

info@rsc.si