SITHERM S361R

SPECIFICATION SHEET

SITHERM S361R is a modified steel grade with high toughness and good thermal fatique at a normal range of hardness for hot-work applications like die casting, extrusion, die forging and hot stamping.

CHEMICAL COMPOSITION (%)

SIJ Metal Ravne	AISI	W. Nr.	C	Si	Mn	Cr	Mo	V	Ni
SITHERM S361R	-	-	0.37	0.25	0.40	4.90	1.80	0.60	1.60

TOUGHNESS

KV impact specimens (EN ISO148-1:2017 / ASTM A370-05-17) are used to test impact toughness in transverse direction. Specimens are quenched and tempered to 45+/-1 HRC and test is performed at 20°C. Average impact toughness of forged quality is higher than 33 Joule for the forging size up to 800 × 400 mm. (acc. NADCA#229-2016).

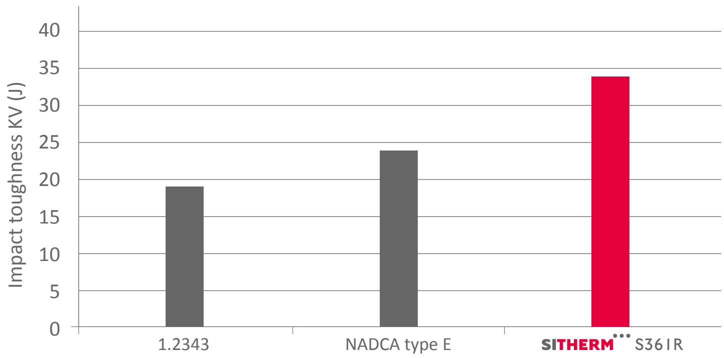

Fig.1: Impact toughness

QUALITY COMPARISON

SITHERM S361R is a premium tool steel of highest toughness produced by SIJ Metal Ravne. The chart below shows its toughness compared to SITHERM 2343, SITHERM 2344 and to SITHERM S350R hot-work steels. Tool steel with increased toughness is critical in applications with a risk of gross cracking.

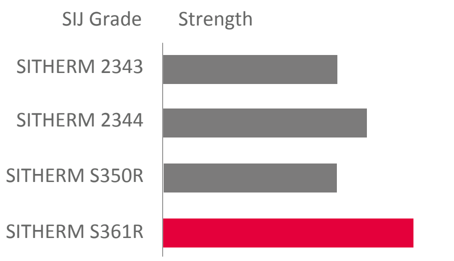

Fig.2: Comparison of strength for hot-work tool steel

Fig.3: Comparison of toughness for hot-work tool steel

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APPLICATIONS

SIHTERM S361R is primarily designed for die casting of light metals and alloys.

Due to its excellent hardenability, it is especially recommended for high-dimension tools. It is often used for highly stressed hot-work structural parts where superior toughness is required.

Steel 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.

SIHTERM S361R is supplied in annealed condition, max. 235 HBW (791 N/mm²).

MICROSTRUCTURE IN THE CONDITION AS DELIVERED

SITHERM S361R is delivered in a soft annealed condition according to NADCA#229 standard.

NADCA#229-2016
Banding / Microsegregation Chart
All microstructures etched with Vilella's reagent

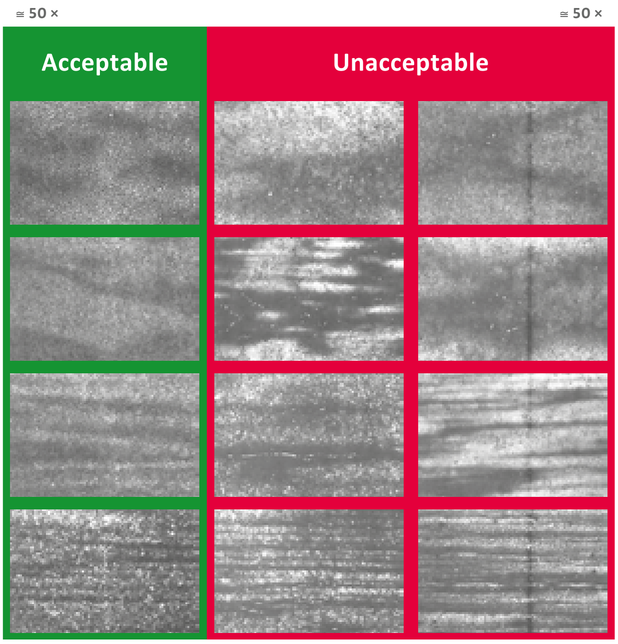

Fig. 4: Microhomogeneity

NADCA#229-2016
Annealed Quality Microstructure Chart – "AS" Rating
(All microstructures etched with 5% Nital)

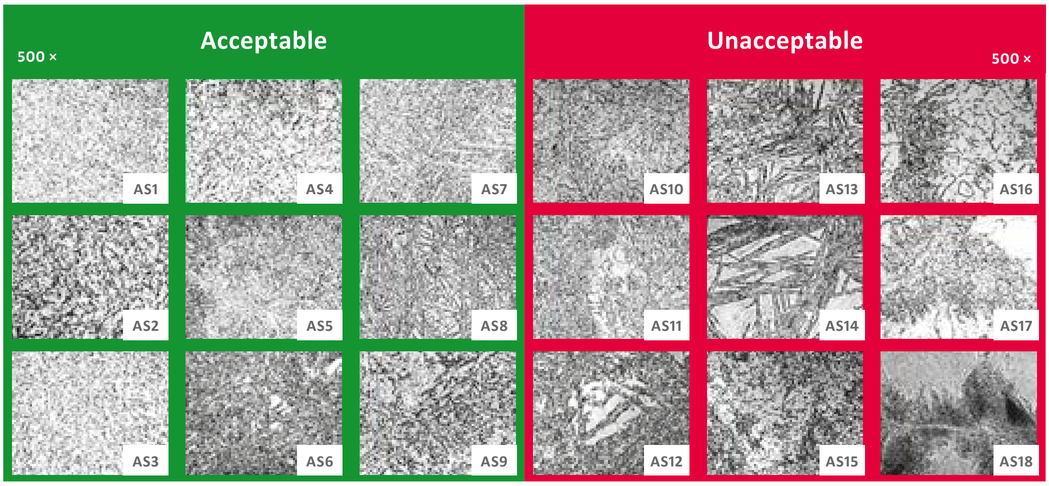

Fig. 5: „AS" – Rating acceptability criteria of annealed microstructure according to NADCA#229-2016, 500 × magnification

NADCA#229-2016
Heat Treatment Quality Microstructure Chart – "HS" Rating
(All microstructures etched with 5% Nital)

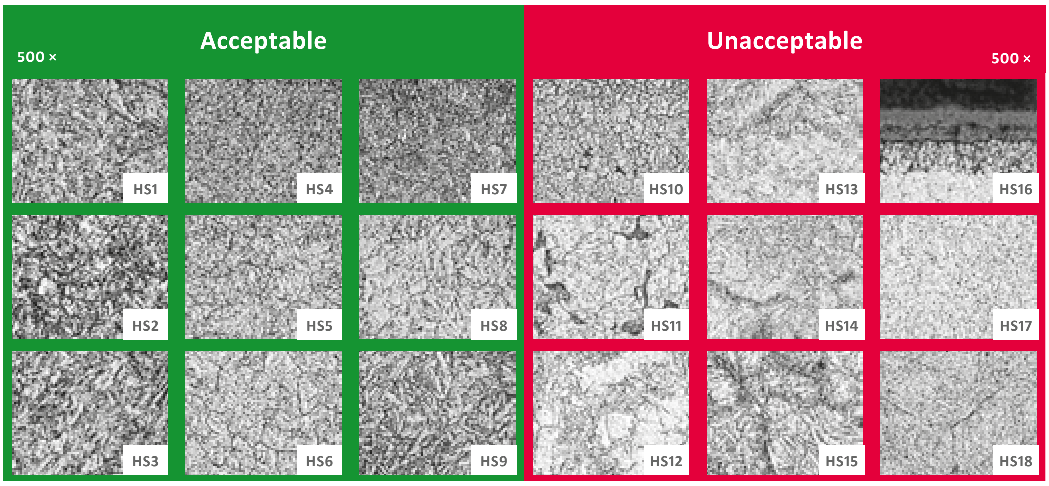

Fig. 6: „HS" – Rating Acceptability criteria of heat treated microstructure according to NADCA#229-2016, 500 × magnification

Microstructure of SITHERM S361R steel

Fig. 7a: Annealed

Fig. 7b: Heat treated (Q+T)

PHYSICAL PROPERTIES

Heat treated: hardened and 2× tempered.

Density

DENSITY (g/cm³)				
20 °C	450 °C	500 °C	550 °C	600 °C
7.83	7.70	7.68	7.66	7.65

Thermal conductivity

THERMAL CONDUCTIVITY [W/mK]				
100 °C	450 °C	500 °C	550 °C	600 °C
32.8	34.3	34.1	33.9	33.5

Electric resistivity

ELECTRIC RESISTIVITY [Ω mm²/m]				
20 °C	450 °C	500 °C	550 °C	600 °C
0.50	0.58	0.63	0.68	0.73

Specific heat capacity

SPECIFIC HEAT CAPACITY [J/gK]				
20 °C	450 °C	500 °C	550 °C	600 °C
0.44	0.64	0.68	0.72	0.83

Modulus of elasticity

MODULUS OF ELASTICITY (10^3 N/mm²)
20 °C
210

Coefficient of Linear Thermal Expansion

COEFFICIENT OF LINEAR THERMAL EXPANSION BETWEEN 20 °C AND [10^{-6} °C^{-1}]				
200 °C	300 °C	400 °C	500 °C	600 °C
11.60	11.8	12.02	12.04	12.01

HEAT TREATMENT

Recommendations or NADCA#229-2016

Annealing:

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

Stress relieving:

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

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 - 1030 °C, ≤150 °C/h	1030 -1050 °C	See CCT diagram
Hold in furnace at T = 650 °C / 850°C until $T_{SURFACE}$-T_{CORE} ≤ 110 °C / 60 °C.	Soaking time: 30 min. after soaking of die surface and core: $T_{SURFACE}$ - T_{CORE} ≤ 12 °C (25) F, or 90 minutes maximum after die surface reaches the specified hardening temperature, whichever occurs first.	Fast cooling is recommended in pressurized N_2. For large dimension hot-work tooling, see NADCA#207 or GM DC-9999-1Rev.18 specification.

TEMPERING DIAGRAM AND IMPACT TOUGHNESS:

Tempering must start immediately after quenching is completed (when part reaches 90-70 ˚C).
Three tempering treatments are recommended in order to fully stabilize the microstructure.

HEATING	TEMPERING TEMPERATURE	COOLING
150 °C/h – 250 °C/h	1st: 540-550 °C 2nd: choose working hardness (see tempering diagram). 3rd: 30-30 °C below 2nd tempering.	Cool in air or in furnace down to room temperature between tempering cycles.
Protect against oxidation, scaling and decarburisation.	1 hour per 25 mm wall thickness based on furnace temperature. Minimum 2 hours.	

Tempering diagrams

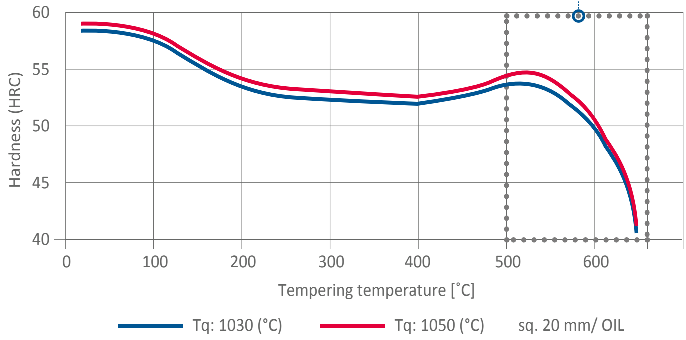

Fig. 8: Tempering diagram

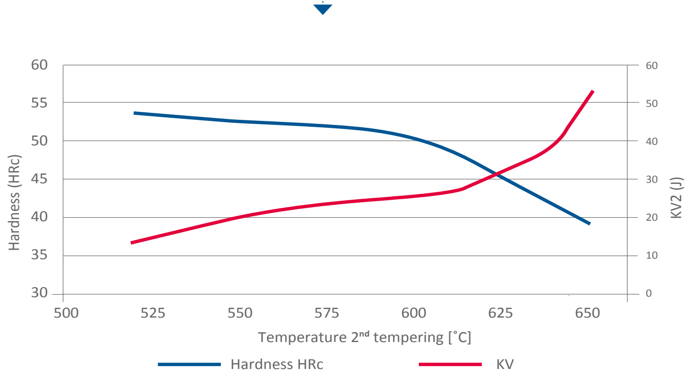

Fig. 9: Imact toughness KV2 vs. hardness HRc

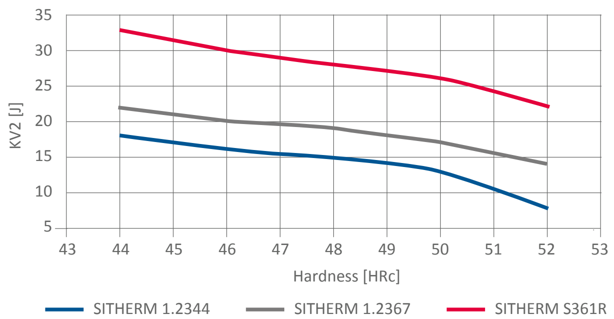

Fig. 10: Comparision hardness vs. impact toughness of hot-work tool steels

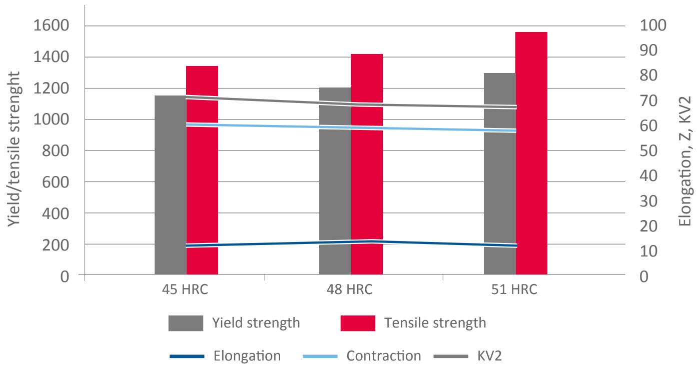

Fig. 11: Mechanical properties of SITHERM S361R at elevated testing temperatures

Impact toughness at elevated temperatures

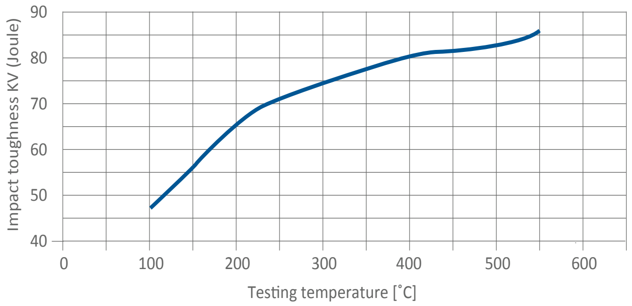

Fig. 12: Impact toughness as a function of testing temperature

Fracture toughness:

Tempering (°C)	100	200	300	400	500	550	600	650
Hardness HRc	58	54	53	52.5	54.5	54	51	41

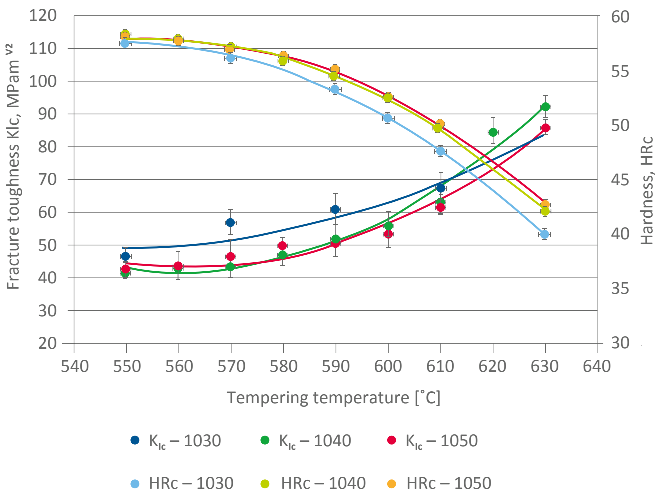

Fig.13: Fracture toughness K_{Ic} vs. hardness HRc

Dimensional changes during hardening and tempering

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

CONTINUOUS COOLING TRANSFORMATION (CCT) DIAGRAM

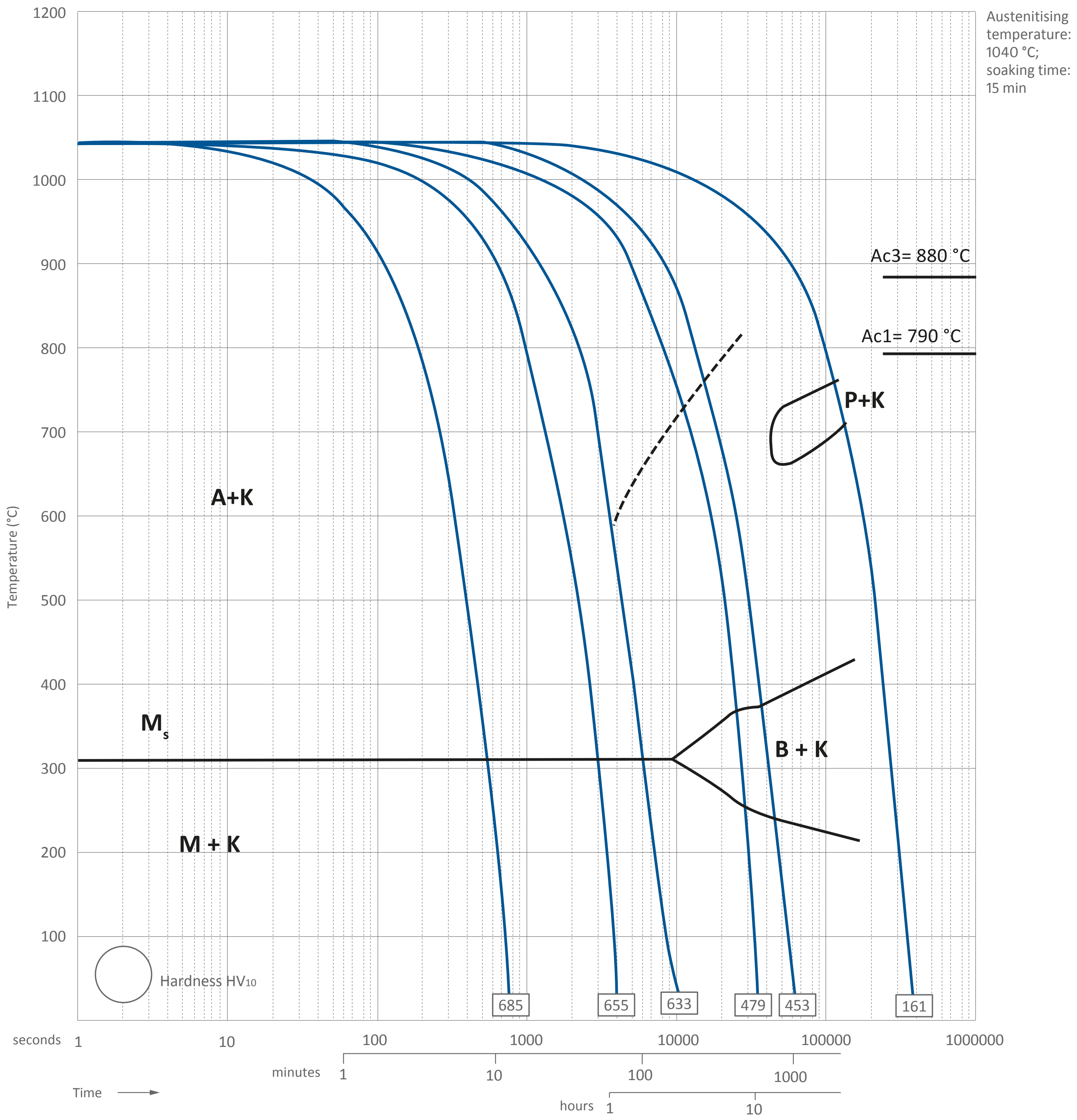

Fig. 15: Continuous Cooling Transformation (CCT) diagram.

Legend:
A - Austenite
K - Carbide
P - Pearlite
M - Martensite
B - Bainite

SURFACE TREATMENT

Nitriding and nitrocarburising

Nitriding treatment is commonly recommended to enhance surface properties of SITHERM S361R.

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 for plastic molding or cold-work applications with wear resistance requirements is performed by producing a surface compound layer of composition and thickness depending on application requirements.

For applications with a 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 nitriding parameters to obtain the required surface properties, please, consult our certified nitriding specialists.

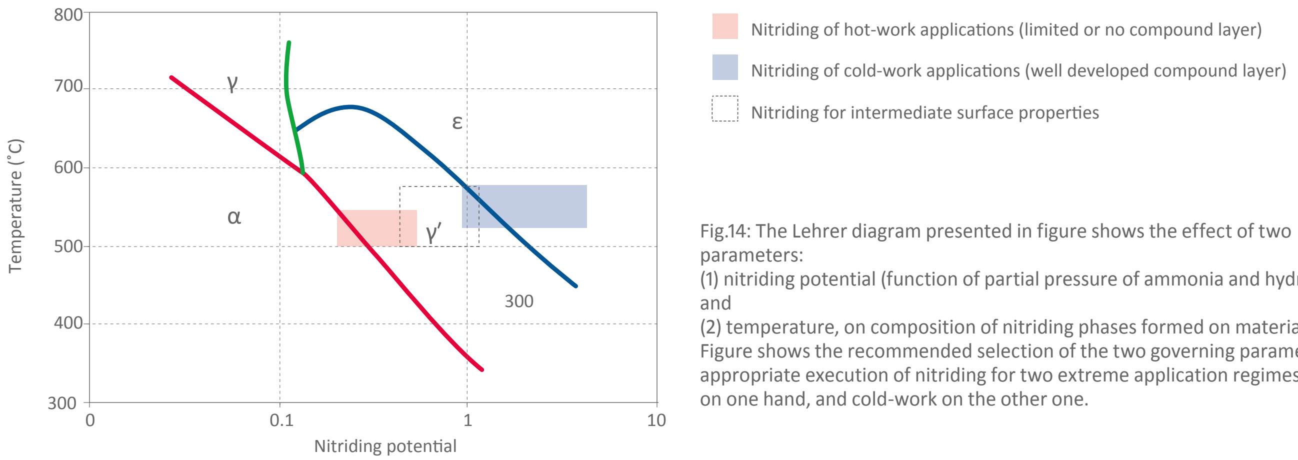

Fig.14: The Lehrer diagram presented in figure shows the effect of two parameters:
(1) nitriding potential (function of partial pressure of ammonia and hydrogen), and
(2) temperature, on composition of nitriding phases formed on material surface.
Figure shows the recommended selection of the two governing parameters for appropriate execution of nitriding for two extreme application regimes, hot-work on one hand, and cold-work on the other one.

DISCLAIMER

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