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XD15NW™

X40CrMoVN16-2

A high hardness, corrosion and fatigue resistance martensitic grade

CONTINUOUS
METALLURGICAL
INNOVATION

SPECIAL STEELS

DEVELOPMENT

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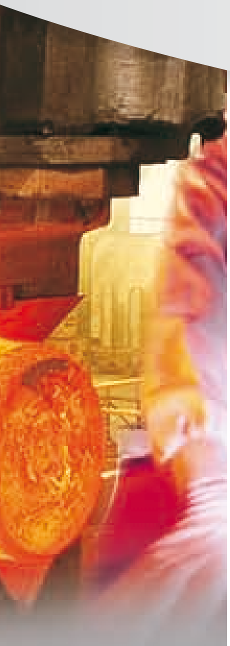
Enhancing your performance



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THE INDUSTRIAL ENVIRONMENT

Numerous industrial applications require the use of stainless steel solutions which must resist high mechanical stress and corrosive environment.

For high stress applications, like bearings, the required hardness is at least 58 HRC. The choice of stainless grades then becomes rather limited. The most common grade is X105CrMo17 and the associated compositions with slight variations of carbon, chromium or molybdenum. Addition of other elements like tungsten, vanadium and niobium can be made in order to improve the temperature resistance. However, for all these grades, the carbon content gives the required hardness and has to be kept at a minimum of 0.7 % to yield 58 HRC.

This high carbon content leads to well-known limitations for these grades:

- Limited corrosion resistance
- Carbide rich structure
- Limited fatigue behavior
- Sensitivity to spalling
- Polishing difficulties

DEVELOPMENT OF XD15NW

The following criteria have been taken into account for the development of this grade:

- HRC ≥ 58 after tempering at low (around 180 °C) and high (500 °C) temperatures.
- Low residual austenite after heat treatment in order to ensure a high dimensional stability of the parts.

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CHARACTERISTICS OF THE GRADE

- Partial substitution of carbon with nitrogen. For steels containing 13-17 % of Cr, the addition of nitrogen through a conventional melting method allows a saturated content of roughly 0.20 %. Combined with 0.4 % to 0.5 % carbon:
  - > A minimum hardness of 58HRC can be ensured,
  - > A low concentration of fine carbides is obtained.
- Nitrogen combined with chromium and molybdenum plays a favorable role in the resistance to pitting corrosion.
- Molybdenum and vanadium ensure a secondary hardening. These elements replace chromium in the precipitate. The chromium content in the matrix is kept at a high level, therefore contributing to an improved corrosion resistance.

APPLICATIONS

- Bearings (ball, roller, spherical).
- Ball and roller-screws.
- Rod ends.

CHEMICAL COMPOSITION

	C	Si	Mn	Cr	Mo	V	N	Ni
min.	0.37	-	-	15.00	1.50	0.20	0.16	-
max.	0.45	0.60	0.60	16.50	1.90	0.40	0.25	0.30

SPECIFICATIONS

- X40CrMoVN16-2
- UNS: S42025
- Euro Number: 1.4123
- AMS: 5925

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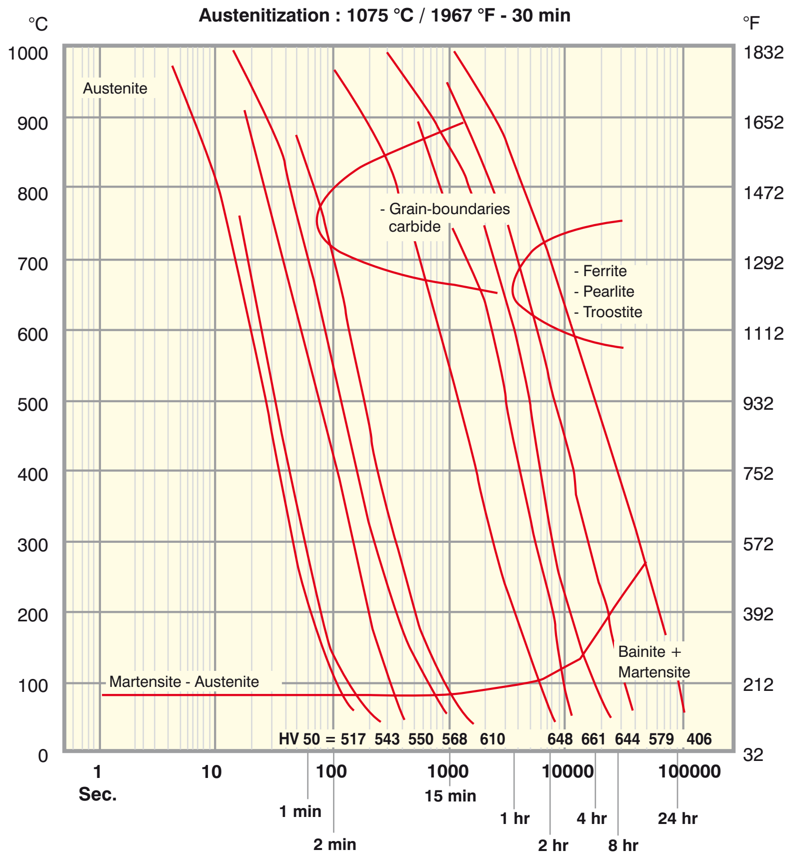
CCT DIAGRAM



Transformation Points

γ	1050 °C	1075 °C
Ac1	850 / 870 °C	
Ac3	890 / 900 °C	
Ms	120 / 130 °C	80 / 100 °C
Mf	- 50 / - 60 °C	- 80 / - 100 °C

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MACROSTRUCTURE

The segregation observed in the ingots is well within the limits of the bearings used in the aerospace industry requirements:

Class	Type	Severity
1	Freckles	A
2	White spots	A
3	Radial segregation	B
4	Ring pattern	B

Macrostructure according to ASTM A 604

CLEANLINESS

The typical values in terms of cleanliness are better than the usual requirements for such a grade.

Typical values according to ASTM E45

A		B		C		D	
Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
0	0	≤ 1	0	0	0	1	0.5

Typical Values according to DIN 50602

K1 ≤ 3

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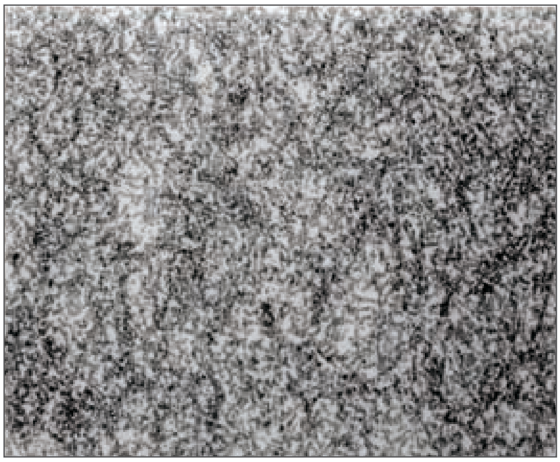
MICROGRAPHIC CHARACTERIZATION

Annealed Condition

The observation of the annealed structure shows a good coalescence of the carbides.

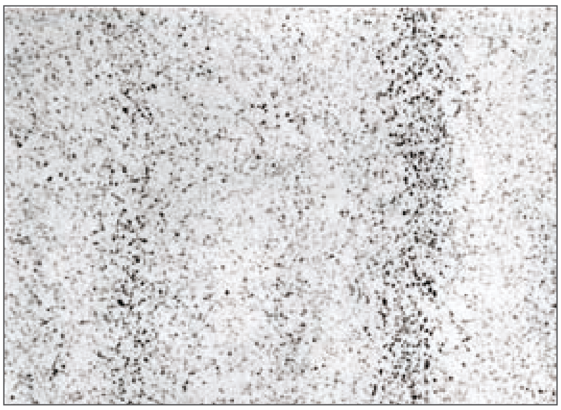


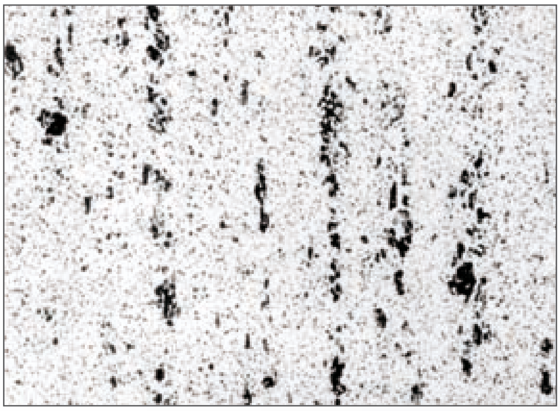
x 100 XD15NW x 500

Heat Treated Condition

Comparatively to X105CrMo17 (440C) the carbides are fine (10 µm) and well distributed within the matrix. The coarse carbides are roughly 20 to 30 µm.

Typical Aspect of the carbides





XD15NW x 200 X105CrMo17

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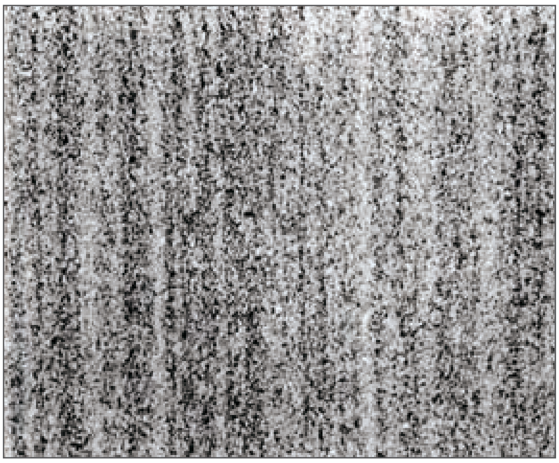
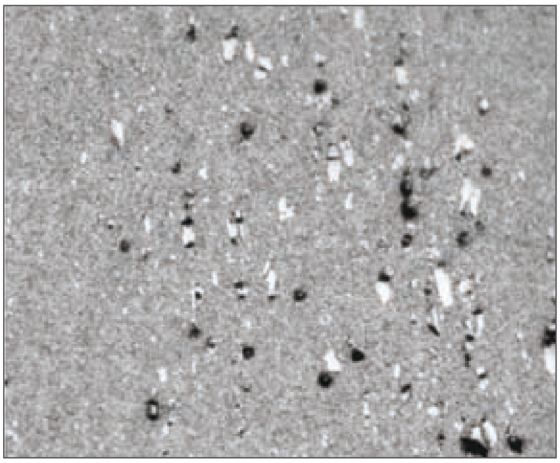
Typical Structure of grades XD15NW
and X105CrMo17 in the used condition





XD15NW **x 100** **X105CrMo17**

MECHANICAL CHARACTERISTICS

Annealed Condition

Annealing cycle:

860 °C / 8 h slow cooling to 550 °C / Air

In the annealed condition the hardness is approximately 250 HB. Typical tensile test results on a 22 mm diameter bar are as follows:

UTS (MPa)	0.2% YS (MPa)	El (%)	Z (%)
820	550	16	45

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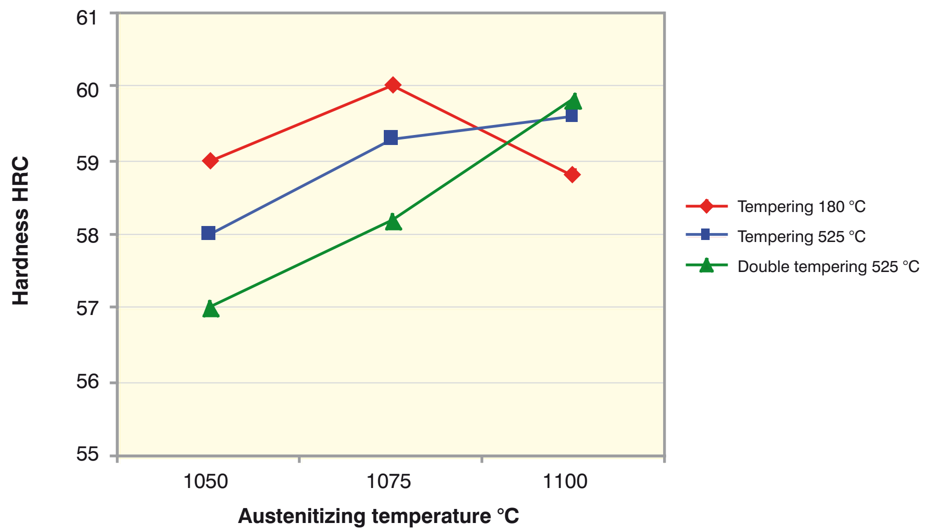
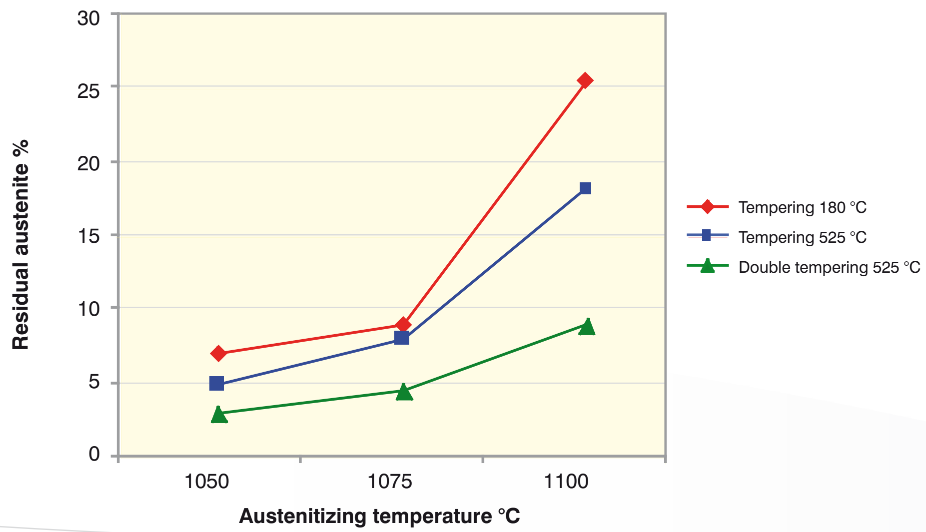
Heat Treated Condition

The heat treatment conditions are optimized in order to jointly obtain the following features:

- Hardness ≥ 58 HRC
- Residual Austenite ≤ 10 %

The following graphs show the influence of the heat treatment conditions on the hardness and the residual austenite content.





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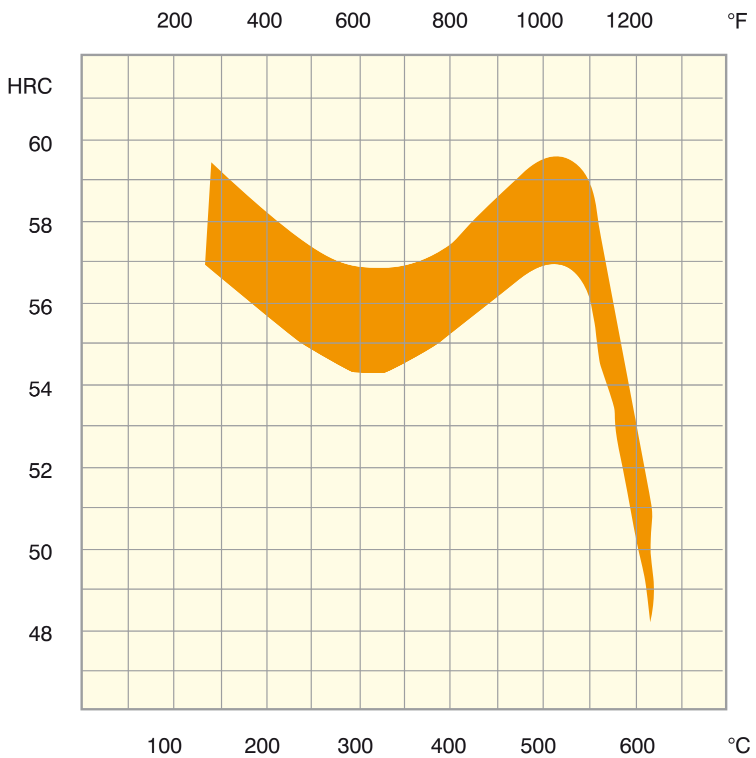
For low tempering temperatures (180 °C), the residual austenite content increases with the austenitizing temperature (γres = 25 % at 1100 °C) and the hardness decreases accordingly.

For high tempering temperatures (525 °C):

- A progressive increase of the residual austenite content with the austenitizing temperature.
- A major influence of the double tempering on the residual austenite content.
- An increase of the hardness with the austenitizing temperature up to a certain limit, followed by a drop due to a high residual austenite content.

The hardness spread for austenitizing temperatures between 980 °C and 1080 °C is shown below:



Based on these results, the optimized heat treatment conditions are presented in the following tables and graphs.

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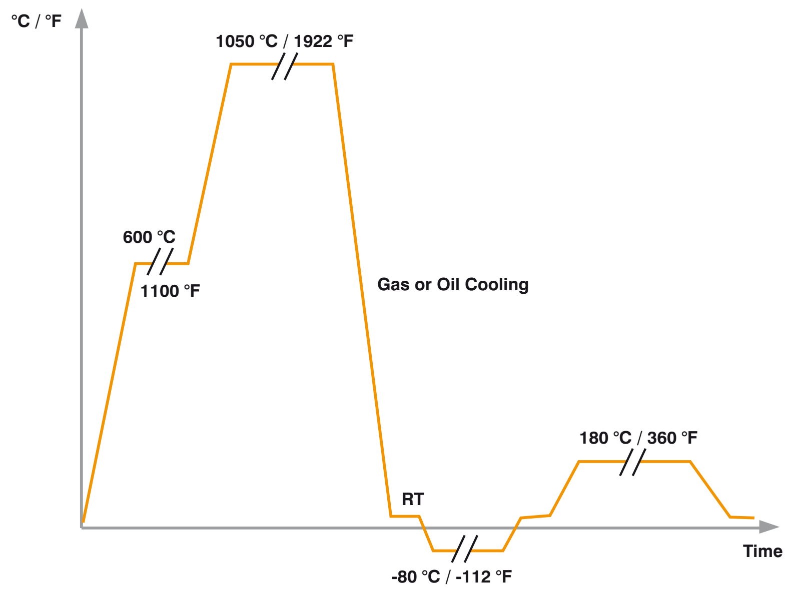
Heat treatment for optimized hardness and corrosion resistance.



HRC	59.2	
HV	695	
Austenite	9 %	
UTS	2320 MPa - 336 ksi	
0.2 % YS	1825 MPa - 265 ksi	
E	4 %	
RA	10%	
Charpy V	10 J - 7.5 ft.lb	
Unnotched impact specimen KNE	20 °C - 68 °F	98 - 110 J 71 - 81 ft.lb
	- 196 °C - 321 °F	98 - 110 J 71 - 81 ft.lb
K1c	14 MPa√m - 12.7 Ksi√in	
Endurance limit 10^7 cycles (Rotative bending)	928 MPa - 135 Ksi	

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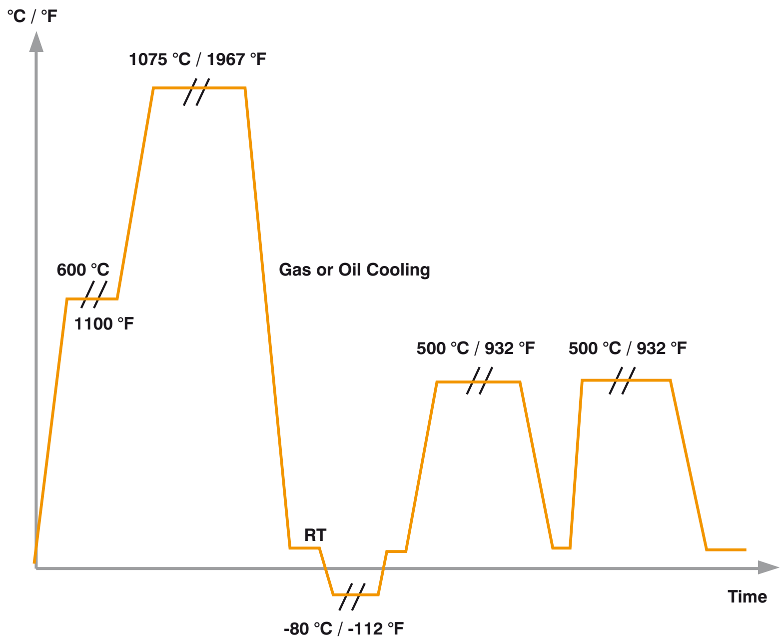
Heat treatment cycle optimized for high working temperatures, high hardness and moderate corrosion resistance.



HRC	59.5
HV	700
Austenite	12 %
UTS	2350 MPa - 340 ksi
0.2 % YS	1580 MPa - 229 ksi
E	4 %
RA	10 %
Charpy V	5.5 J - 4.5 ft.lb
K1c	16 MPa√m - 14.6 Ksi√in
Endurance limit 10^7 cycles (Rotative bending)	954 MPa - 138 Ksi

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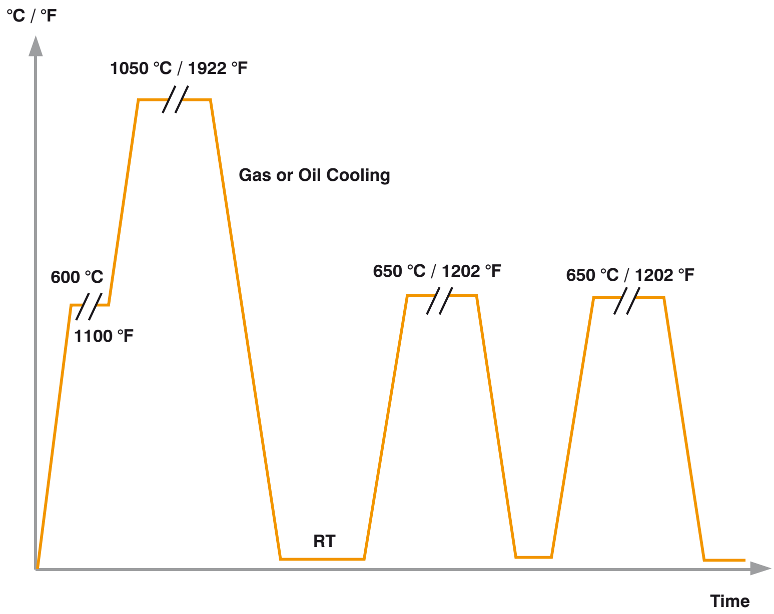
Recommended heat treatment cycle for subsequent surface induction hardening.
The tempering temperature can be adapted to the required core hardness.



HRC	36
Austenite	12 %
UTS	1200 MPa - 174 ksi
0.2 % YS	900 MPa - 131 ksi
E	12 %
RA	40 %
Charpy V	10 J - 7.5 ft.lb
K1c	66 MPa√m - 60 Ksi√in
Endurance limit 10^7 cycles (Rotative bending)	640 MPa - 131 Ksi

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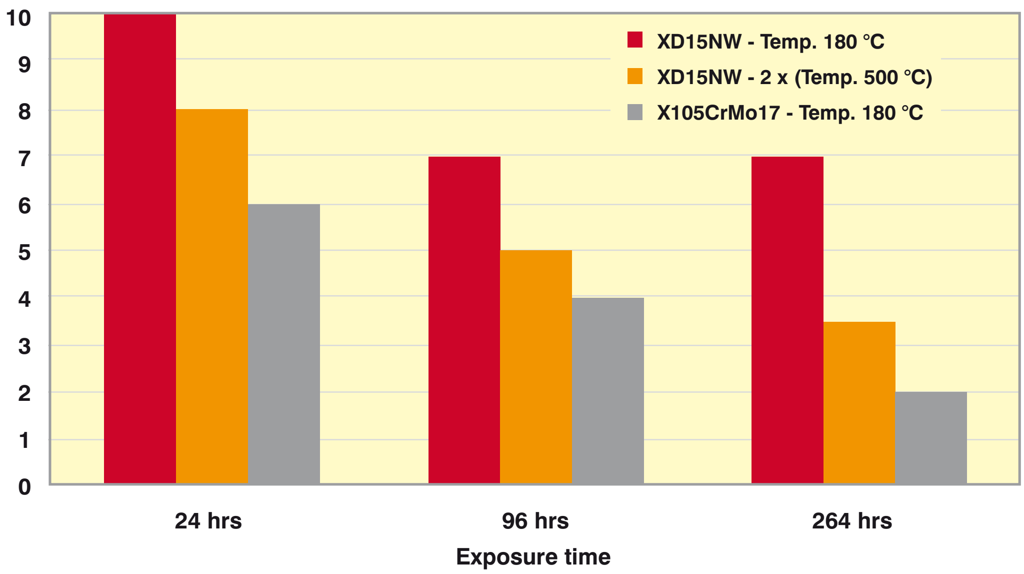
CORROSION RESISTANCE

The corrosion resistance is characterized below with two different tests:

- Salt spray test according to NF X 41-002
- Electrochemical test (potentiocinetic) - H_2SO_4 – 1% - de-aerated

Salt spray test

The results are presented with a normalized scale taking into account the oxidized surface.



These results show the benefit of low temperature tempering in terms of corrosion resistance compared to higher tempering conditions. The decrease in corrosion resistance for the higher tempering temperature is due to the formation of secondary carbides, which consume part of the chromium. The matrix is therefore less rich in chromium and less resistant to corrosion.

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As shown in the pictures below, the corrosion resistance is significantly better when compared to the standard solution X105CrMo17 (440C).

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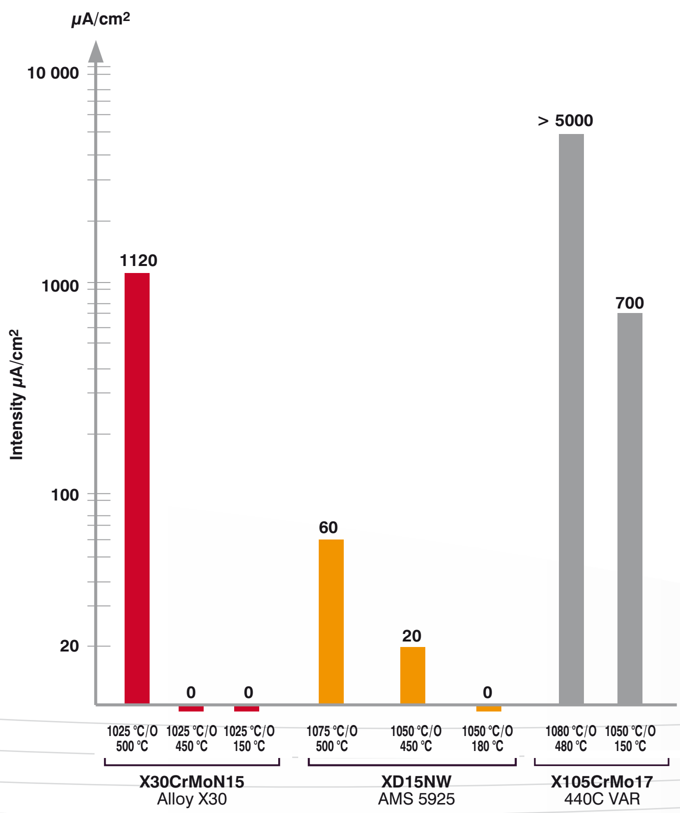
X105CrMo17 (440C)

Aspect of the surface after a 96 h salt spray (NaCl) exposure.
For both grades, heat treatment cycle: 1050 °C Oil / -75 °C / 180 °C.

Potentiocinetic corrosion in de-aerated H_2SO_4 - 1 % solution

The following graph shows the response to this test. The superiority of XD15NW over 440C (X105CrMo17) is confirmed. XD15NW shows equivalent behaviour to X30CrMoN15.



Current density results

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MACHINING

The parameters presented below are indicative only. These parameters have to be optimized based on the type of machining, machines, tools, know-how...

ANNEALED CONDITION

Turning (insert)

Roughing

- Speed: 65 m/min
- Feed: 0.50 mm/rev
- Depth: 2 to 5 mm
- Intensive lubrication.

Finishing

- Speed: 70 m/min
- Feed: 0.10 to 0.30 mm/rev
- Depth: 0.3 to 0.5 mm
- Intensive lubrication.

Milling (insert)

Roughing

- Speed: 65 m/min
- Feed: 0.15 mm/tooth
- Depth: 2 to 5 mm
- Intensive lubrication.

Finishing

- Speed: 70 m/min
- Feed: 0.12 mm/tooth
- Depth: 0.3 to 1.5 mm
- Intensive lubrication.

Drilling (carbide tool)

- Drill diameter: 3 to 30 mm
- Cutting speed: 60 m/min
- Feed: 0.07 to 12 mm/rev

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Design:

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