

AUBERT & DUVAL



GKP™ (W - YW)

32CrMoNiV5

**An innovative steel for
very deep nitriding**

**CONTINUOUS
METALLURGICAL
INNOVATION**

SPECIAL STEELS

RESEARCH

DEVELOPMENT

SERVICE

Enhancing your performance

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THE INDUSTRIAL ENVIRONMENT

Numerous products require hard surfaces resistant to abrasion coupled with structural cores. These products can be obtained with local nitriding.

Nitriding solutions offer very hard surfaces, high compressive stresses and therefore high fatigue properties. Nevertheless, the nitriding depth is often limited to 500 microns which is not suitable for numerous applications.

AUBERT&DUVAL has developed a new nitriding grade, GKP, which offers:

- deeper nitriding depth (up to 1mm),
- or reduced nitriding time for a given depth,
- increased removal stock for grinding or repairs.

This solution is used in the aerospace industry, motor racing and industrial transmissions among others.

DEVELOPMENT OF GKP GRADE

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

- Capable of very deep nitriding,
- Capable of the UTS and YS of the main high temperature carburized solutions (M50Nil) for instance,
- High ductility and fracture toughness,
- No modification of the nitriding process compared to other nitriding grades, like 32CDV13/33CrMoV12-9, 40CrMoV13-9...

APPLICATIONS

- Heavily loaded gears for the aerospace industry or other industrial applications,
- Shafts in the aerospace or motor racing industries,

CHEMICAL COMPOSITION

%	C	Si	Mn	Cr	Ni	Mo	V	Al
min.	0.29	--	0.70	1.10	0.50	0.90	0.20	0.10
max.	0.36	0.30	1.20	1.60	1.00	1.40	0.40	0.30

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SPECIFICATIONS

- 32CrMoNiV5
- UNS: K23280
- AMS: 6496 Air melted
- 6497 Remelted
- 6498 Double vacuum melted

COMPARISON OF DIFFERENT STEELS

	A&D Grades	Designations	C	Ni	Cr	Mo	V
Through hardened steel	RA50YW	80MoCrV42-16 1.3551 / M50 AMS: 6491	0.83	--	4.15	4.25	1.00
Carburized steels	FADC (W - YW)	10NiCrMo13-5 9310 AMS: 6265	0.10	3.25	1.20	0.10	--
	50NILYW	13MoCrNiV42-46-14 M50NIL	0.13	3.40	4.15	4.25	1.20
Nitrided steels	GH4 (W - YW)	40CrMoV13-9 1.8523	0.40	--	3.00	1.00	0.20
	GKH (W - YW)	33CrMoV12-9 AMS: 6481	0.33	--	3.00	1.00	0.20
	GKP (W - YW)	32CrMoNiV5 AMS: 6496-6497-6498	0.32	0.80	1.40	1.20	0.30

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COMPARISON OF THE CORE CHARACTERISTICS OF DIFFERENT STEELS

	A&D Grades	Heat treatment		UTS (MPa / Ksi)	0.2% YS (MPa / Ksi)	E (%)	KV (J / ft.lb)
Through Hardened steel	RA50YW	1100°C / Gas -75°C 3 x 550°C		HRC: 60 - 63			
Carburized steels	FADC (W - YW)	825°C / Oil -75°C 150°C		1150 / 467	900 / 131	14	140 / 103
	50NILYW	1100°C / Oil -75°C 3 x 540°C		1400 / 203	1200 / 174	15	12 / 9
Nitrided steels	GH4 (W - YW)	825°C / Oil 600°C		1400 / 203	1150 / 167	13	40 / 29
	GKH (W - YW)	920°C Oil	600°C	1250 / 181	1060 / 154	15	130 / 96
			640°C	1080 / 157	900 / 131	19	170 / 125
	GKP (W - YW)	940°C Oil	600°C	1430 / 207	1280 / 186	14	50 / 37
			640°C	1250 / 181	1075 / 156	16	80 / 59

COMPARISON OF SURFACE CHARACTERISTICS

	A&D Grades	Heat treatment	Use temperature	Surface hardness
Through Hardened steel	RA50YW	1100°C / Gas -75°C 3 x 550°C	< 450°C	HRC: 60 / 63
Carburized steels	FADC (W - YW)	825°C / Oil -75°C 150°C	< 150°C	HRC ≥ 60
	50NILYW	1100°C / Oil -75°C 3 x 540°C	< 400°C	HRC ≥ 60
Nitrided steels	GH4 (W - YW)	825°C / Oil 600°C	< 450°C	HV: 850
	GKH (W - YW)	920°C / Oil 600°C	< 450°C	HV: 850
	GKP (W - YW)	940°C / Oil 640°C	< 450°C	HV: 900

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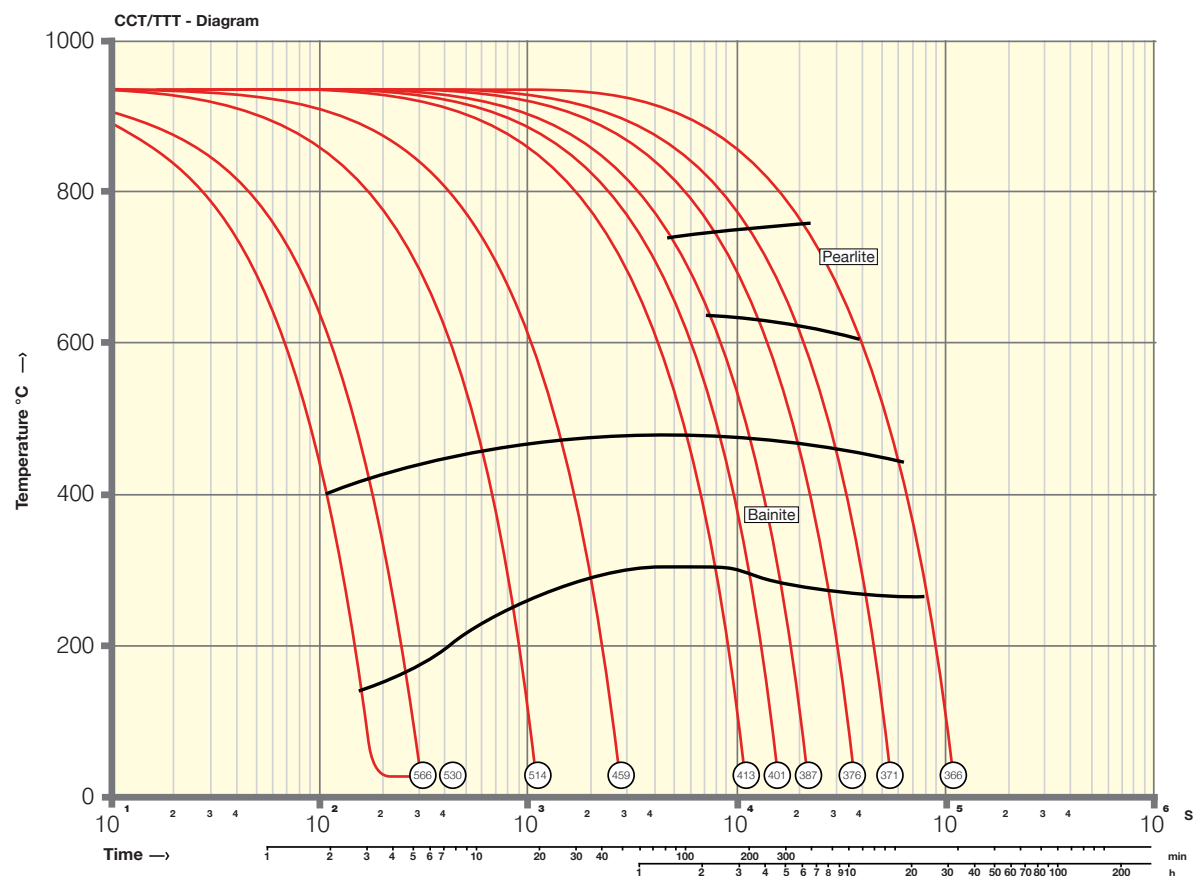
MAIN PHYSICAL PROPERTIES

Density: 7.8

Mean coefficient of Thermal Expansion:

Temperature range		10 ⁻⁶ /m/m/°C	10 ⁻⁶ /in/in/°F
°C	°F		
20 / 100	68 / 212	11.8	6.55
20 / 500	68 / 932	13.6	7.55

CCT DIAGRAM



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Ac1	760°C / 1400°F
Ac3	850°C / 1562°F

MACROSTRUCTURE

The segregations observed on the ingots are well within the limits of the aerospace industry requirements:

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

Macrostructure according to ASTM A 604



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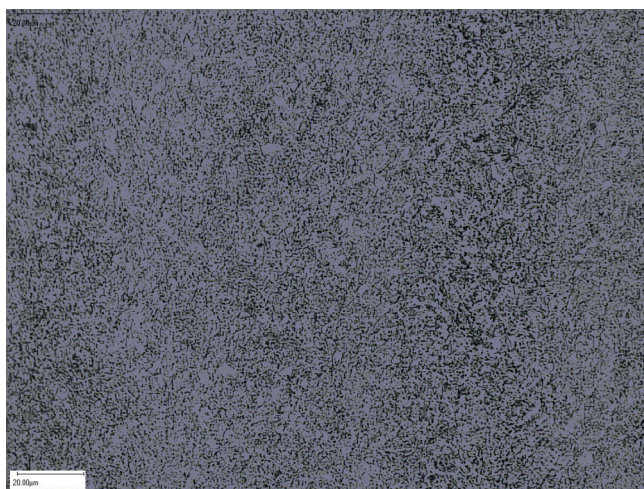
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MICROGRAPHIC CHARACTERIZATION

Annealed condition

Heat to 875°C / 1607°F followed by slow cooling.

Brinell hardness: 240



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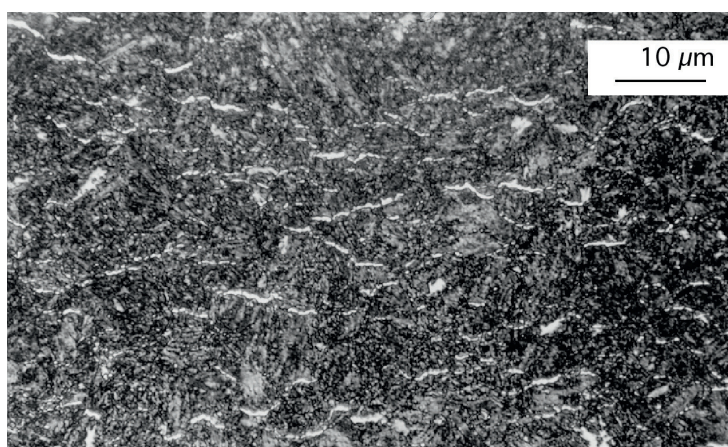
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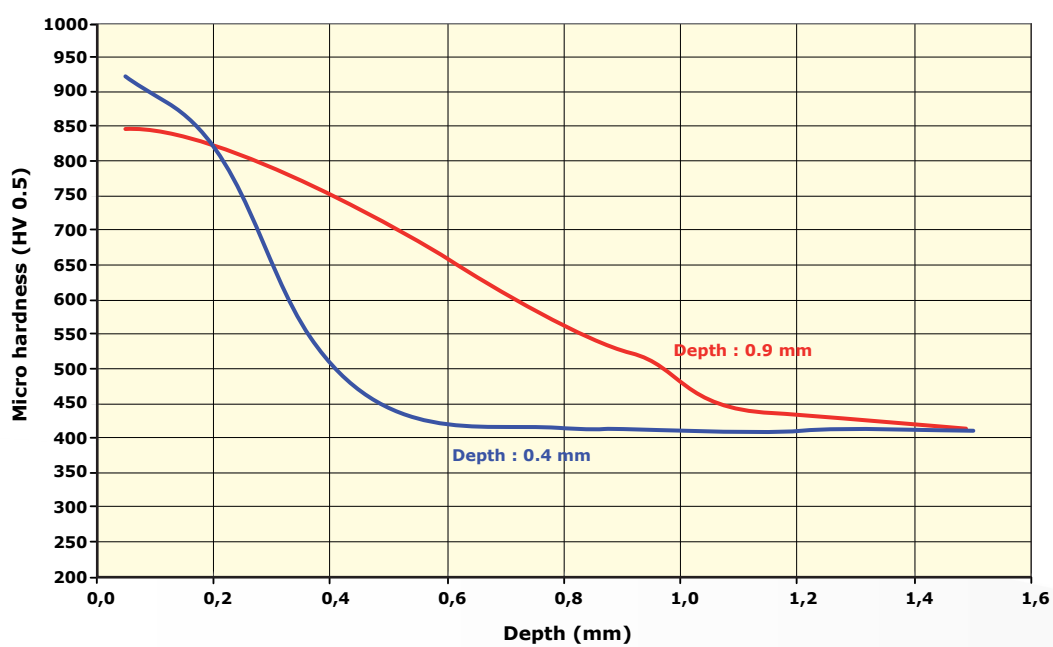
Heat treated condition

- 940°C / 1724°F
- Oil quench
- Tempering 640°C / 1184°F
- Nitriding

Typical aspect of the structure
(Nitrided Layer)



Examples of deep nitriding



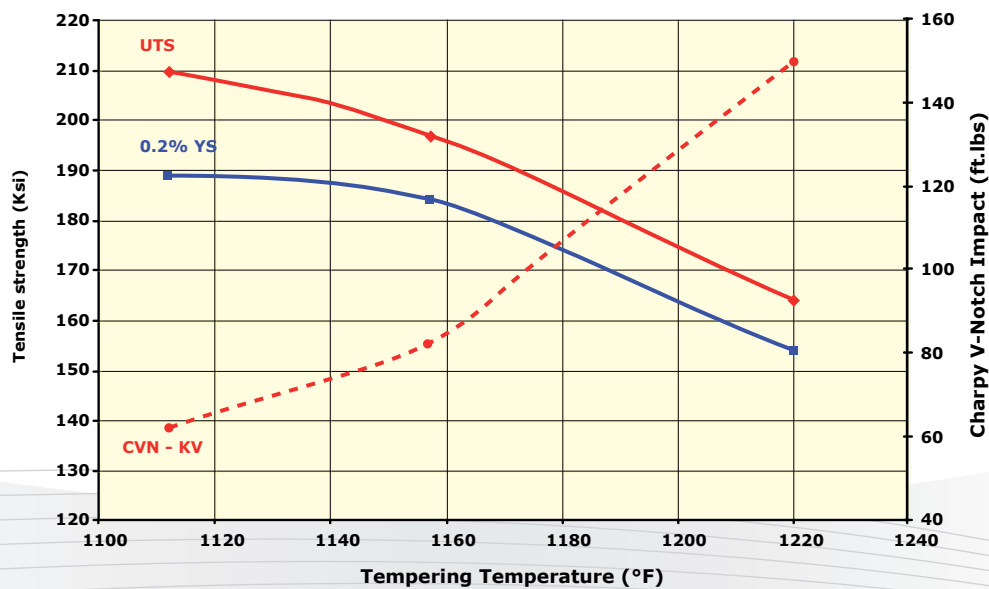
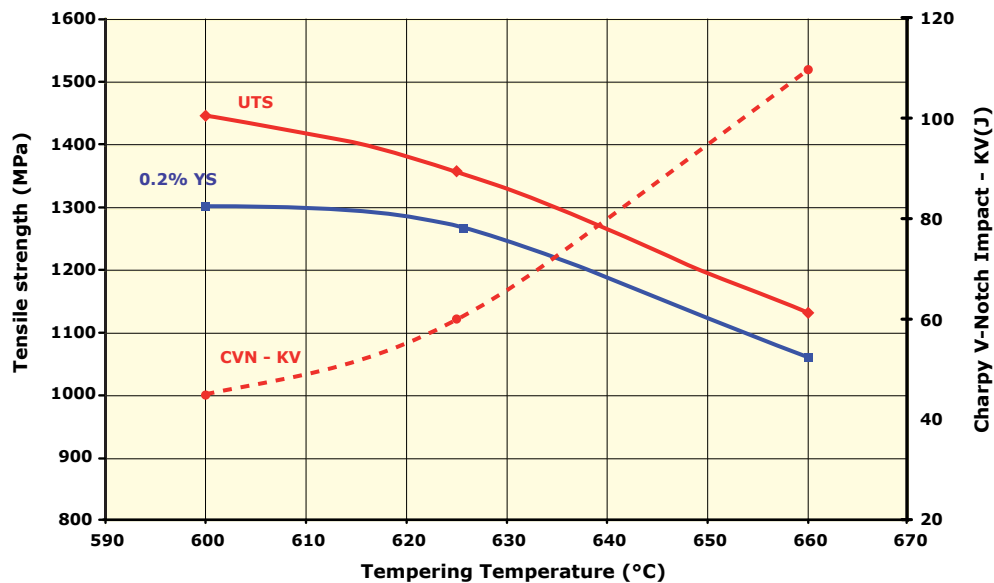
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MECHANICAL CHARACTERISTICS VARIANCE WITH THE TEMPERING TEMPERATURE

Heat Treatment

- 940°C / 1724°F – 30 min
- Oil quenching
- Tempering



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Rotative bending

$R = -1$

$K_t = 1.035$

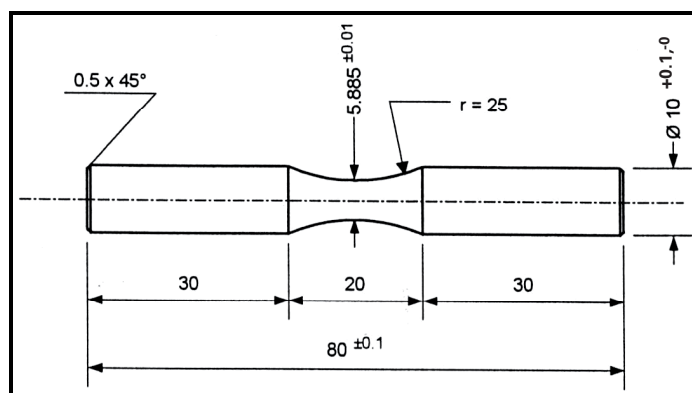
Polished samples

Fatigue limit for $2 \cdot 10^7$ cycles,
50% chance of failure

Heat treatment:

- $940^\circ\text{C} / 1724^\circ\text{F} - 30 \text{ min}$
- Oil quenching
- Tempering $630^\circ\text{C} / 1166^\circ\text{F} - 2 \text{ hrs}$
- Nitriding:

T:	$\leq 530^\circ\text{C} / 986^\circ\text{F}$
Duration:	$\geq 180 \text{ hrs}$
Depth:	0.8 mm



Mechanical characteristics

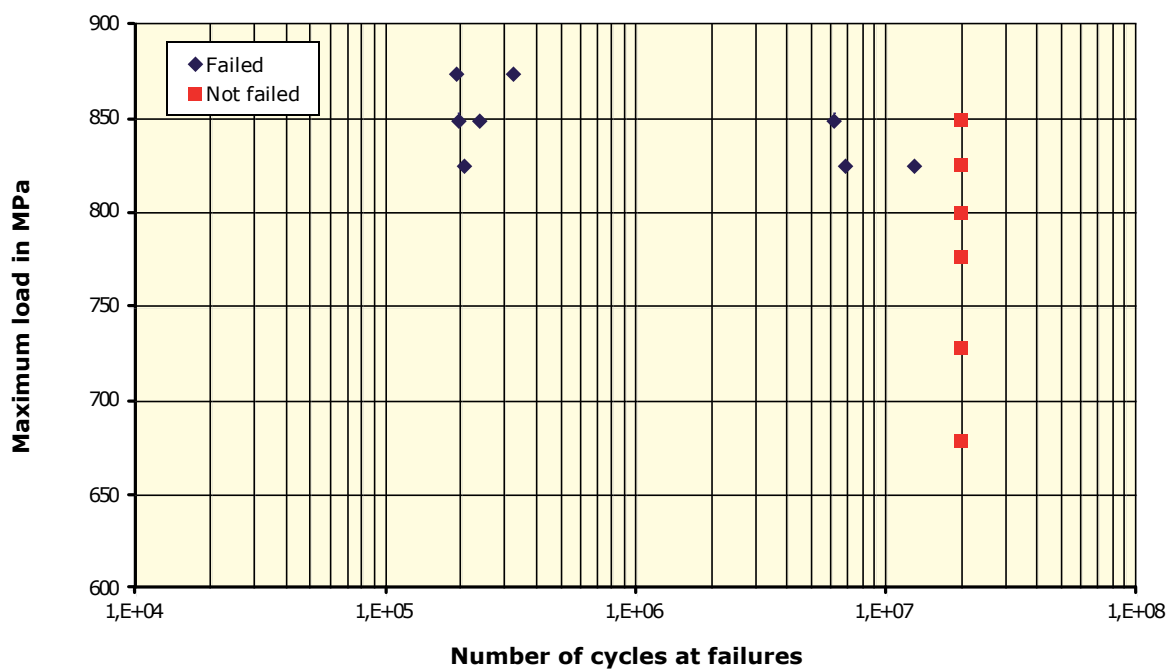
- UTS: 1348 MPa
- 0.2 YS: 1248 MPa
- Fatigue limit $2 \cdot 10^7$ cycles:
 - Base metal: 840 MPa / 122 Ksi
 - Nitriding: $> 1360 \text{ MPa} / 197 \text{ Ksi}$



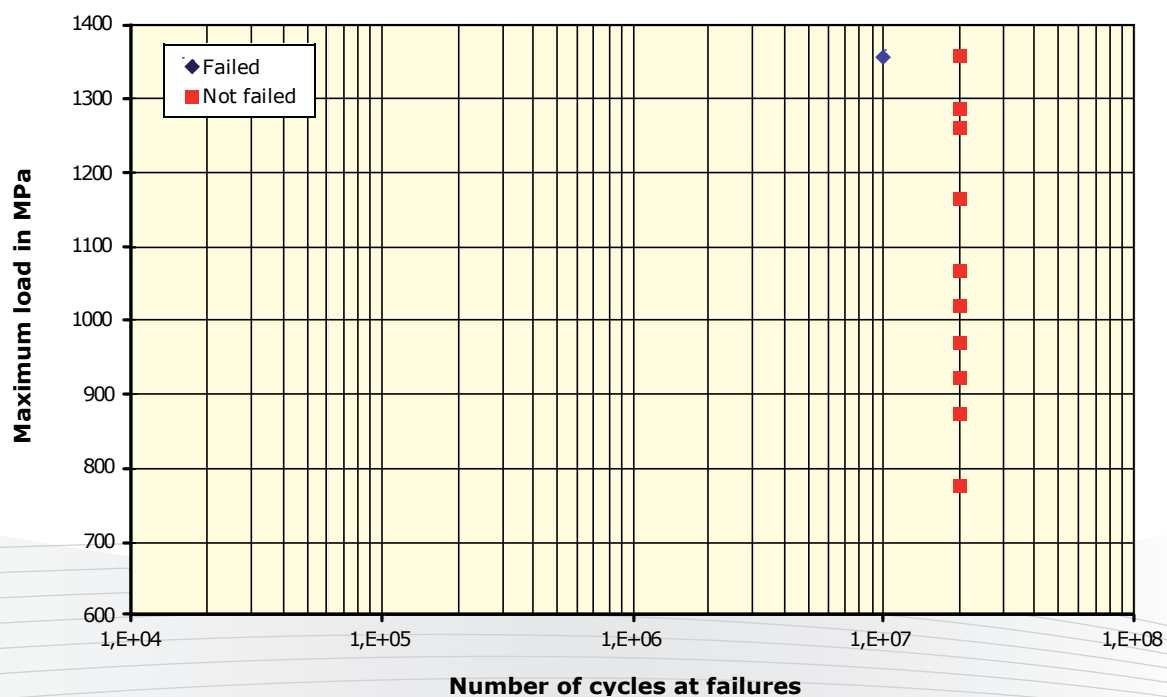
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Rotative bending S/N curve – Base metal



Rotative bending S/N curve – Nitriding



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Comparison of the fatigue limit of different surface hardenable steels

R = -1

Kt = 1.035

Polished samples

Fatigue limit for $2 \cdot 10^7$ cycles, 50% chance of failure

	A&D Grades	Heat treatment	UTS (MPa / Ksi)	0.2% YS (MPa / Ksi)	Lf core material (MPa / Ksi)	Lf case hardened (MPa / Ksi)	Case depth
Through Hardened steel	RA50YW	1100°C / Gas -75°C 3 x 550°C	HRC: 60 - 63		950 138	--	--
Carburized steels	FADCW	825°C / Oil -75°C 150°C	1150 467	900 131	600 / 87	1050 / 152	DC550: 1.3 mm
	50NILYW	1100°C / Oil -75°C 3 x 540°C	1400 203	1200 174	750 / 109	1075 / 156	DC550: 1.3 mm
Nitrided steels	GH4YW	825°C / Oil 600°C	1400 203	1150 167	810 / 112	1150 / 167	HVcore + 100: 0.6 mm
	GKHYW	920°C / Oil	1250 181	1060 154	825 / 120	> 1200 > 174	HVcore + 100: 0.6 mm
	GKPYW	940°C / Oil 640°C	1250 181	1075 156	840 / 122	> 1330 > 193	HVcore + 100: 0.8 mm

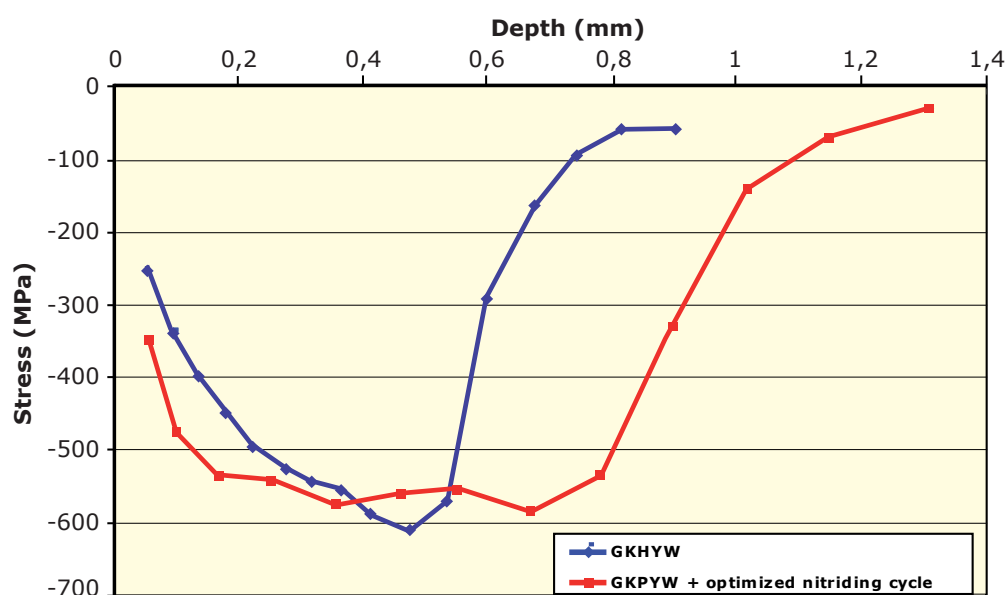
Effect of residual stresses in nitrided layer

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SURFACE PROPERTIES

Compressive stress in a nitrided layer



Comments:

The profiles shown here are indicative. Any profile can be obtained.

The extent of the nitrided layer allows:

- 1 – Replacing carburized solutions with nitrided solutions
(increased fatigue life, simplified fabrication process, increased working temperatures...),
- 2 – Increased removal stock for grinding.

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