

AUBERT & DUVAL



FDGTM (W)

20NiCrMo13-4

**A carburizing steel
to minimize heat treatment
distortion**

**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 carburizing of low carbon steel grades.

The carburizing solutions available so far have shown limitations in terms of hardenability, often requiring oil quenching. The severity of this type of quenching induces major distortions which need to be “repaired” by machining.

Aubert & Duval has developed a simple solution which can be gas quenched, **FDG**. This solution is used in the aerospace and motor sport industries among others.

DEVELOPMENT OF FDG GRADE

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

- Capable after gas quenching of the UTS and YS of the main solutions available (9310, 9315, S82),
- High ductility and fracture toughness,
- Suited for the production of large parts with oil quenching,
- No modification of the carburizing process compared to 9310, 9315 or S82.

APPLICATIONS

- Heavily loaded gears for the aerospace industry,
- Gears for motor racing,
- Any transmission part (shafts...),
- Defense,
- Parts with a high risk of distortion.



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CHEMICAL COMPOSITION

%	C	Si	Mn	Cr	Mo	Ni
min.	0.17	0.15	0.30	0.80	0.30	3.00
max.	0.22	0.40	0.60	1.20	0.50	3.50

SPECIFICATIONS

- 20NiCrMo13-4
- 1.6660
- UNS: K41910
- AMS: 6492 (Air melted)
6493 (Remelted)



UNS: K41910
AMS 6492 (Air Melted), 6493 (Remelted)

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COMPARISON OF DIFFERENT CASE HARDENING STEELS

A&D Grades	Designations	Use temperature	C	Si	Ni	Cr	Mo	V	Cu
FADC (W)	10NiCrMo13-5 9310 AMS: 6265	< 100°C	0.10	0.10	3.25	1.20	0.10	--	--
FADH (W)	14NiCrMo13-4 BS: S157 - 1.6657	< 100°C	0.16	0.25	3.20	1.00	0,25	--	--
FADS (W)	16NiCrMo16-5 BS: S82 - 1.6723	< 100°C	0.16	--	4.25	1.20	0.20	--	--
BXM	18CrNiMo7-6 1.6587	< 100°C	0.17	0.30	1.60	1.60	0.30	--	--
50NILYW	13MoCrNiV42-16-14 M50NIL	< 400°C	0.13	--	3.40	4.15	4.25	1.20	--
FND(W)	15NiMoSiCr10 AMS: 6494 - 6495	< 250°C	0.15	1.10	2.50	1.00	2.00	--	--
FDG(W)	20NiCrMo13 1.6660 AMS: 6492 - 6493	< 100°C	0.20	0.20	3.20	1.00	0.50	--	--
AMS 6308 0.90Si - 1.0Cr - 2.0Ni - 3.2Mo - 2.0Cu - 0.10V (0.07 - 0.13C)		< 100 °C	0.10	1.00	2.00	1.00	3.25	0.10	2.00

COMPARISON OF THE CORE CHARACTERISTICS OF DIFFERENT CASE HARDENING STEELS

A&D Grades	Designations	Heat Treatment*	UTS (MPa/Ksi)	0.2% YS (MPa/Ksi)	E (%)	KV (J/ft.lb)
FADC (W)	10NiCrMo13-5 9310 AMS: 6265	825°C / Oil -75°C / 150°C	1150 / 167	900 / 131	14	140 / 103
FADH (W)	14NiCrMo13-4 BS: S157 - 1.6657	825°C / Oil -75°C / 150°C	1350 / 196	1000 / 145	14	140 / 103
FADS (W)	16NiCrMo16-5 BS: S82 - 1.6723	825°C / Oil -75°C / 150°C	1450 / 210	1150 / 167	12	65 / 48
BXM	18CrNiMo7-6 1.6587	850°C / Oil -75°C / 150°C	1400 / 203	1150 / 167	12	75 / 55
50NILYW	13MoCrNiV42-16-14 M50NIL	1100°C / Oil -75°C / 3 x 540°C	1400 / 203	1200 / 174	15	12 / 9
FND(W)	15NiMoSiCr10 AMS: 6494 - 6495	960°C / Gas -75°C / 300°C	1350 / 196	1100 / 160	13	130 / 96
FDG(W)	20NiCrMo13 1.6660 AMS: 6492 - 6493	825°C / Oil -75°C / 150°C	1450 / 210	1000 / 145	13	110 / 81
		825°C / Gas -75°C / 150°C	1350 / 196	1030 / 149	13	110 / 81
AMS 6308 0.90Si – 1.0Cr – 2.0Ni – 3.2Mo – 2.0Cu – 0.10V (0.07 – 0.13C)		913°C / Oil -75°C 2 x 200°C	1172 / 170	965 / 140	16	118 / 87

* After carburizing + annealing

UNS: K41910
AMS 6492 (Air Melted), 6493 (Remelted)

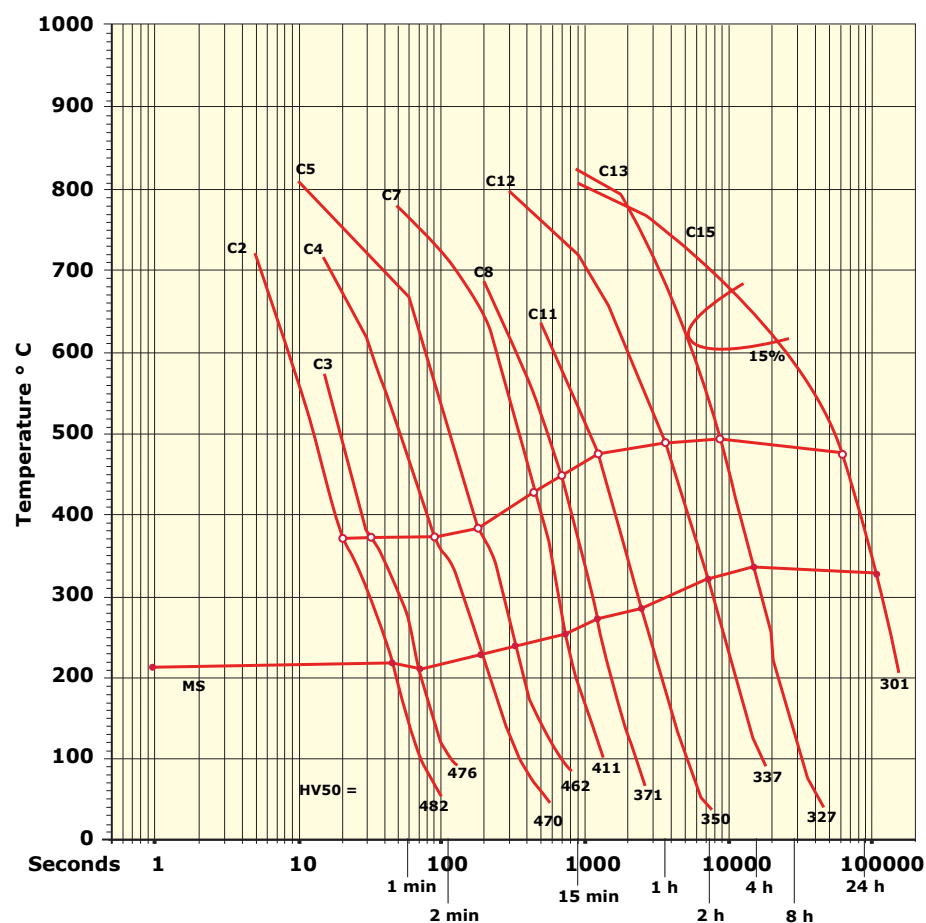
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20NiCrMo13-4

TRANSFORMATION POINTS

γ	825°C / 1517°F
Ac1	680°C / 1256°F
Ac3	820°C / 1508°F
Ms	210°C / 410°F

CCT DIAGRAM





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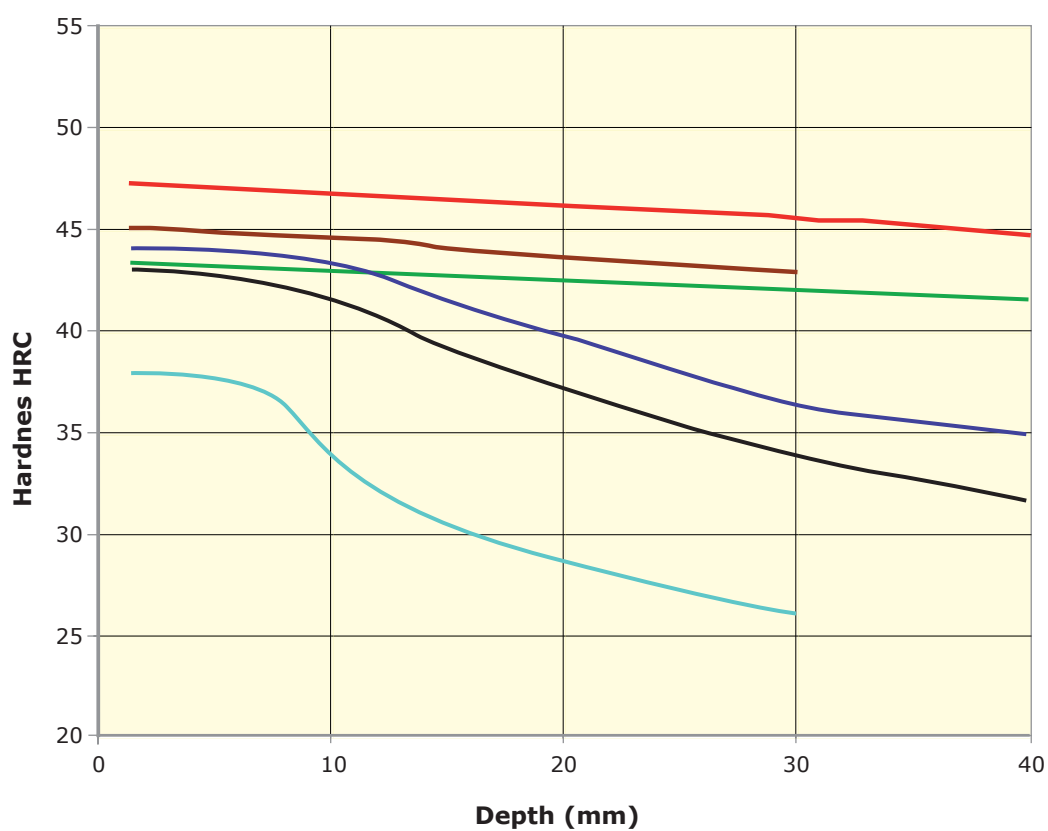
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JOMINY CURVES

The JOMINY curves clearly show that **FDG** is capable of

- Large parts
- Homogeneous properties

whereas FADC and FADH see their properties dropping dramatically after a few millimeters despite a strong cooling rate.



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MACROSTRUCTURE

The segregation, as measured on the ingots, complies with the tightest requirements. Below is an example for remelted grades for the aerospace industry:

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 remelted grade.

Typical values according to ASTM E45

A		B		C		D	
Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
0.5	0.5	1.0	0.5	0.5	0.5	1.0	1.0



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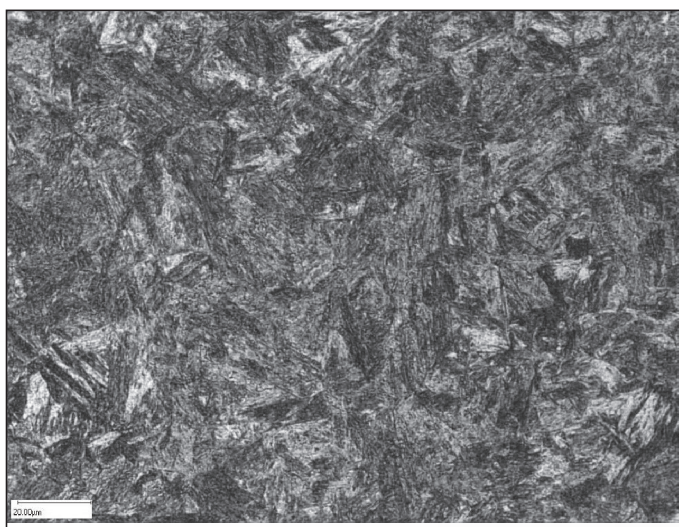
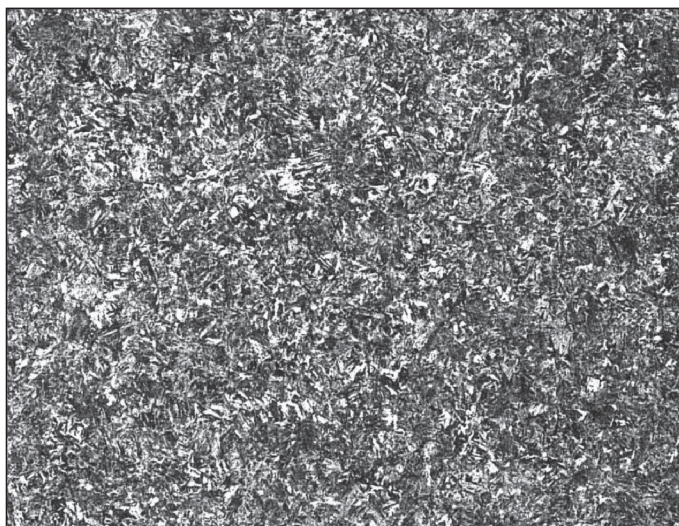
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MICROGRAPHIC CHARACTERIZATION

Annealed Condition

Heat to 675°C / 1247°F followed by slow cooling.

Brinell hardness: 235



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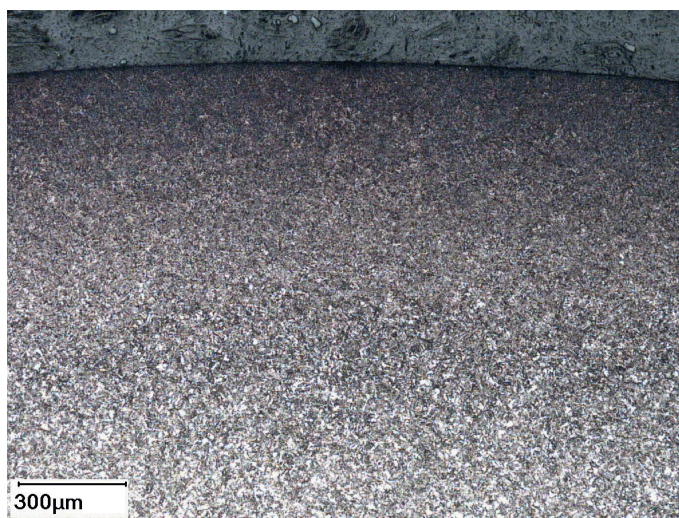
Heat treated condition

Case Hardening

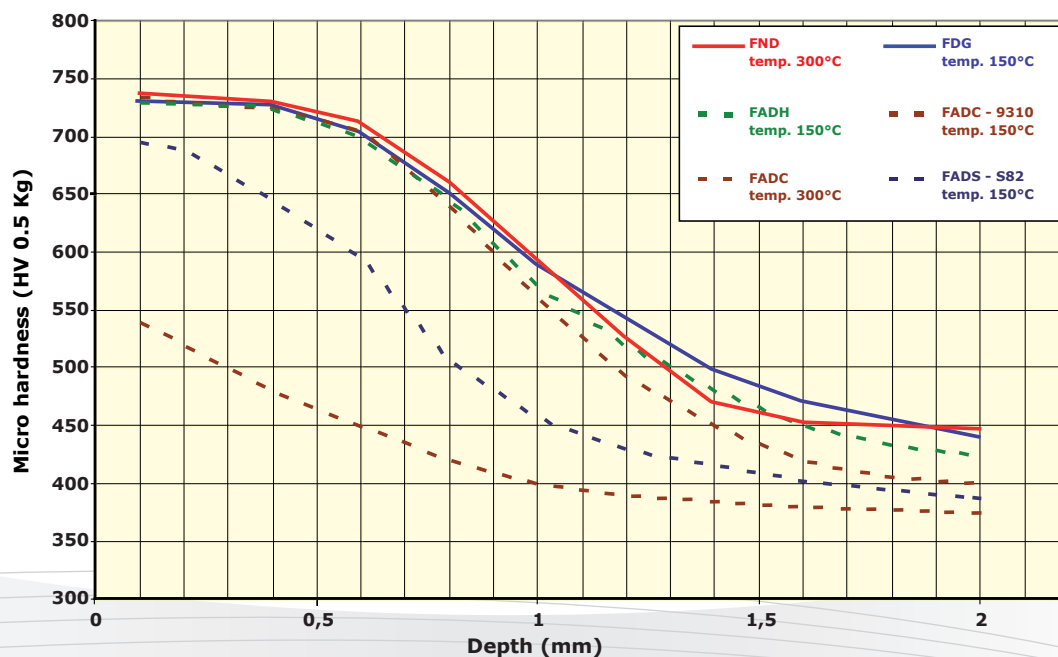
Heat treatment

- 825°C / 1517°F – Oil quenching
- -75°C / -103°F – 2 hrs
- Tempering 150°C / 302°F – 2 hrs

Typical aspect of the structure
(carburized layer)



Comparison of hardness profiles



UNS: K41910
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MECHANICAL PROPERTIES

Heat Treatment:

- **Oil quench** from 825°C / 1517°F. Sub-zero -75°C / -103°F. Temper at 150°C / 302°F

Typical values:

- UTS: 1450 MPa / 203 Ksi
- 0.2 % YS: 1100 MPa / 145 Ksi
- El: 13 %
- KV: 130 J / 96 ft.lb

- **Gas quench** (3 bars) 825°C / 1517°F. Sub-zero -75°C / -103°F. Temper at 150°C / 302°F

Typical values:

- UTS: 1350 MPa / 196 Ksi
- 0.2 % YS: 1000 MPa / 149 Ksi
- El: 13 %
- KV: 110 J / 81 ft.lb

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Rotative bending

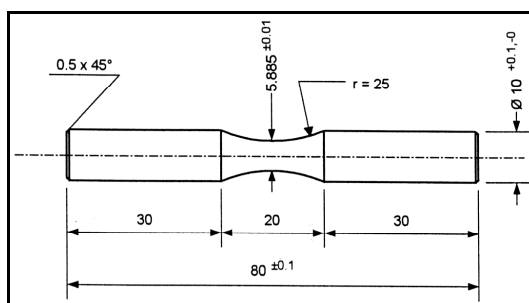
$R = -1$

$K_t = 1.035$

Polished samples

Fatigue limit for $2 \cdot 10^7$ cycles,

50% chance of failure



Annealing

Case hardening

- Depth DC500: 1.3 mm

Heat treatment

- 825°C / 1517°F – Oil quenching
- -75°C / -103°C – 2 hrs
- Tempering 150°C / 302°F – 2 hrs

Mechanical characteristics

Heat treated material (base metal)

- UTS: 1513 MPa / 200 Ksi
- 0.2 % YS: 1132 MPa / 147 Ksi
- Fatigue limit $2 \cdot 10^7$ cycles: 890 MPa / 106 Ksi

Case hardened and heat treated material

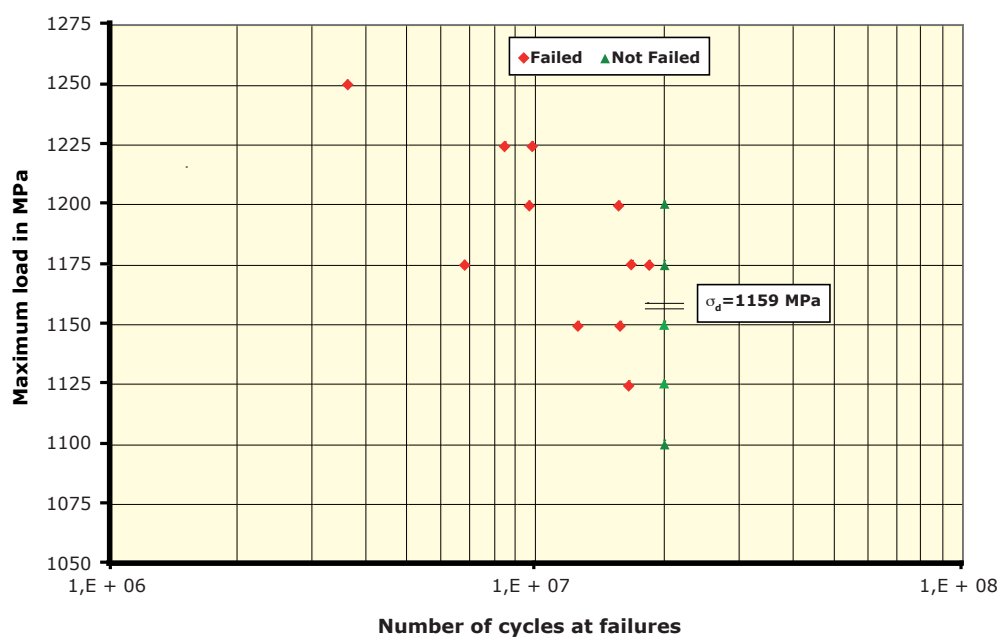
- Fatigue limit $2 \cdot 10^7$ cycles: 1159 MPa / 158 Ksi



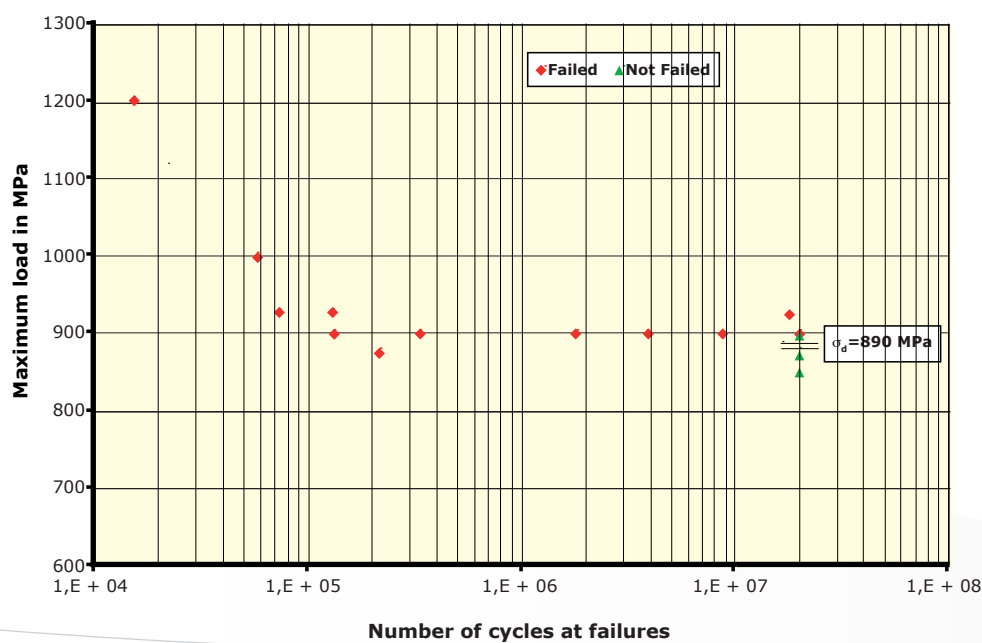
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Rotative bending fatigue S/N curve – case hardened



Rotative bending fatigue S/N curve – core material



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Comparison of the fatigue limit of different surface hardenable steels

Rotative bending

R = -1

Kt = 1.035

Polished samples

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

A&D Grades	Designations	Heat treatment	UTS (MPa / Ksi)	0.2% YS (MPa / Ksi)	Lf core (MPa / Ksi)	Lf case (MPa / Ksi)	Case depth DC550
FADC (W)	10NiCrMo13-5 9310 AMS: 6265	825°C / Oil -75°C 150°C	1150 / 467	900 / 131	600 / 97	1050 / 152	1.3 mm
50NILYW	13MoCrNiV42-16-14 M50NIL	1100°C / Oil -75°C 3 x 540°C	1400 / 203	1200 / 174	750 / 109	1075 / 156	1.3 mm
FADH (W)	14NiCrMo13-4 BS: S157 - 1.6657	825°C / Oil -75°C 150°C	1350 / 196	1000 / 145	760 / 110	1100 / 160	1.2 mm
FND (W)	15NiMoSiCr10 AMS: 6494 - 6495	960°C / Gas -75°C 250°C	1350 / 196	1030 / 149	729 / 106	1093 / 158	1.0 mm
FDG (W)	20NiCrMo13 1.6660 AMS: 6492 - 6493	825°C / Oil -75°C 150°C	1450 / 210	1100 / 160	890 / 129	1160 / 168	1.3 mm
		825°C / Gas -75°C 150°C	1350 / 196	1000 / 145	715 / 104	1210 / 175	1.2 mm





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The information and the data presented herein are typical or average values and are not a guarantee of maximum or minimum values. Applications specifically suggested for material described herein are made solely for the purpose of illustration to enable the reader to make his own evaluation and are not intended as warranties, either express or implied, of fitness for these or other purposes. Aubert & Duval's liability shall not extend, under any circumstances, to the choice of the Product and its consequences.

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