AUBERT&DUVAL

FND™(W)

15NiMoSiCr10

Carburizing steel for high service temperature

CONTINUOUS
METALLURGICAL
INNOVATION

SPECIAL STEELS

DEVELOPMENT

RESEARCH

SERVICE

Enhancing your performance

FND

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THE INDUSTRIAL ENVIRONMENT

Numerous applications require hard surfaces resistant to abrasion coupled with tough, ductile cores. These parts can be obtained with local carburizing of low carbon steel grades. Carburizing solutions are often limited in terms of resistance to temperature, unless the materials are heavily alloyed (cobalt,…).

Aubert & Duval has developed a simple solution which can be oil or gas quenched and tempered at a temperature up to 300 °C / 572 °F, **FND.** This solution is used in the aerospace industry, motor racing, injection systems…

DEVELOPMENT OF THE GRADE FND

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

- Capable of the UTS and YS of the main solutions available (9310, 9315, S82) after gas quenching,
- High ductility and fracture toughness,
- Capable of large parts with oil quenching,
- Retaining high surface hardness after tempering at 300 °C / 572 °F.

UNS: K51570
AMS 6494 (Air Melted), 6495 (Remelted)

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CHARACTERISTICS OF THE GRADE

FND (W) is designed for modern heat and surface treatment facilities:

- Low pressure (2 - 5 bars) gas quenching:
  - No oil quenching: saves cost of degreasing and effluent treatment.
  - Low distortion: saves machining cost after treatment.
  - High mechanical properties: reduce weight and increase performance.

- High temperature resistance:
  - Operating temperature up to 250 °C / 482 °F: increases performance.
  - Compatible with PVD coating (200 – 350 °C / 392 – 662 °F): reduces friction coefficient and improves wear resistance.

APPLICATIONS

- Heavily loaded gears for the aerospace industry,
- Gears for motor racing,
- Any transmission part operating up to 250 °C / 482 °F (shafts,…)
- Injection systems,…

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CHEMICAL COMPOSITION

	C	Mn	Si	Cr	Ni	Mo	V
min.	0.10	--	0.90	0.80	2.30	1.70	--
max.	0.20	1.00	1.30	1.20	2.70	2.20	0.50

SPECIFICATIONS

- 15NiMoSiCr10
- UNS: K51570
- AMS: 6494 (Air melted)
  6495 (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	--
FDG (W)	20NiCrMo13 1.6660 AMS: 6492 - 6493	< 100 °C	0.20	0.20	3.20	1.00	0.50	--	--
FND (W)	15NiMoSiCr10 AMS: 6494 - 6495	< 250 °C	0.15	1.10	2.50	1.00	2.00	--	--
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	825°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*
FDG (W)	20NiCrMo13 1.6660 AMS: 6492 - 6493	825°C / Oil - 75°C / 150°C	1450 / *210*	1100 / *160*	13	130 / *96*
		825°C / Gas - 75°C / 150°C	1350 / *196*	1000 / *145*	13	110 / *81*
FND (W)	15NiMoSiCr10 AMS: 6494 - 6495	960°C / Gas - 75°C / 300°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

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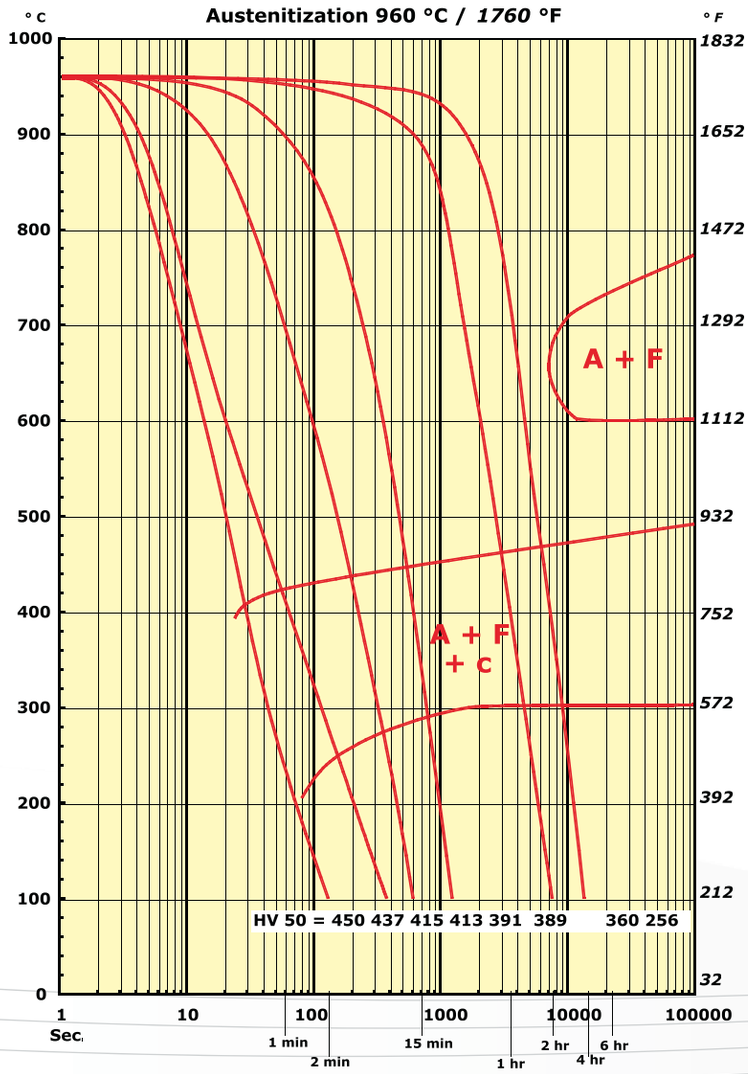
TRANSFORMATION POINTS

γ	960 °C / 1760 °F
Ac1	750 °C / 1382 °F
Ac3	930 °C / 1706 °F
Ms	380 °C / 716 °F

CCT DIAGRAM



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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:

Classe	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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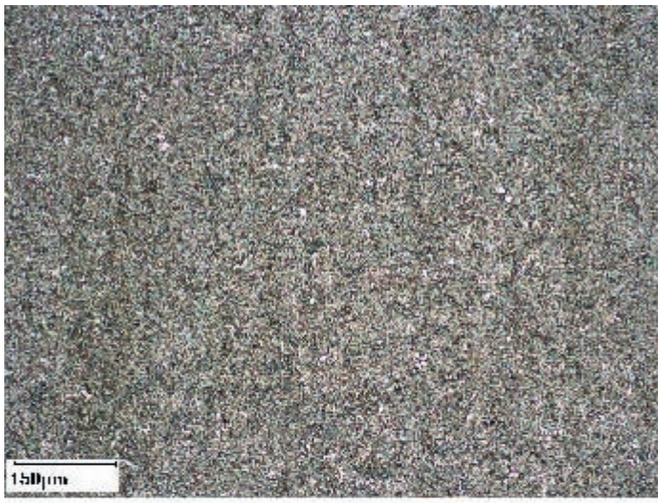
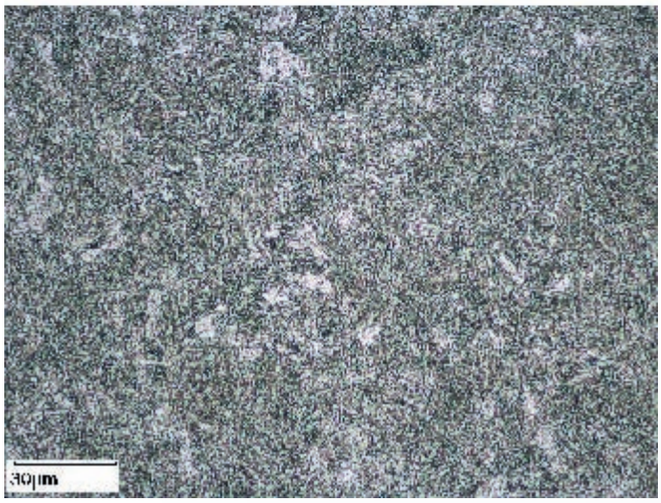
MICROGRAPHIC CHARACTERIZATION

Annealed Condition

Heat to 860 °C / 1580 °F followed by slow cooling
Brinell hardness: < 285





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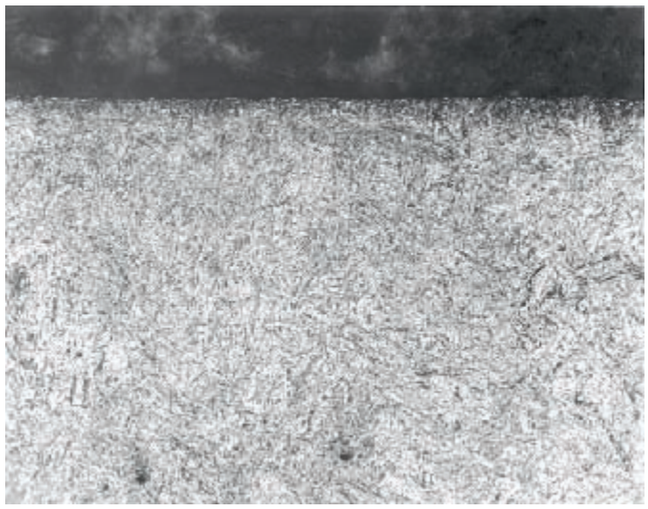
Heat treated condition

Case Hardening

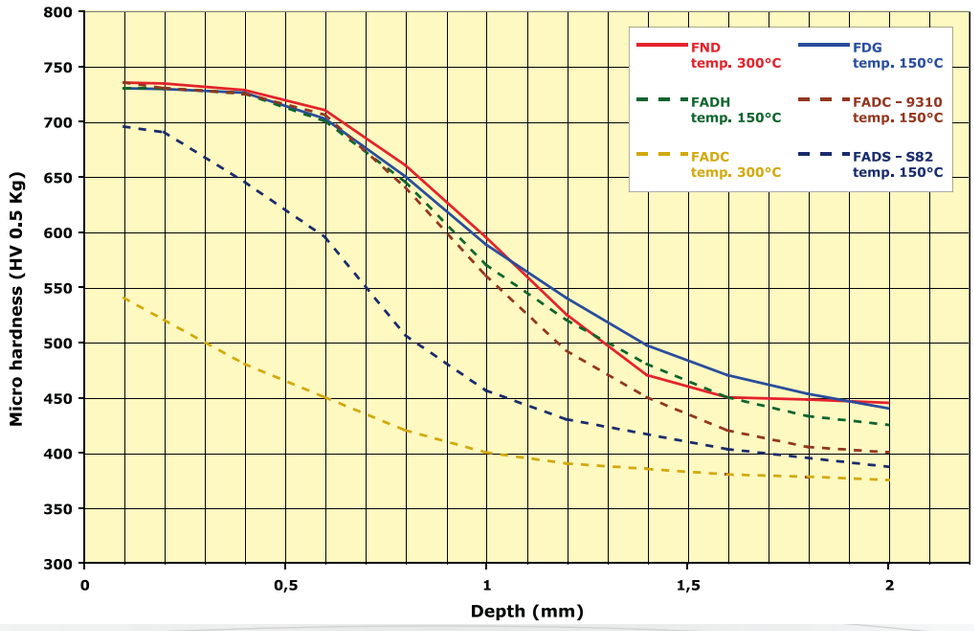
Heat treatment to apply:

- 960 °C / 1760 °F - Gas quenching
- -75 °C / -103 °F - 2 hrs
- Tempering 300 °C / 572 °F - 2 hrs

Typical aspect of the structure (carburized layer)



Comparison of hardness profiles



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MECHANICAL CHARACTERISTICS

Heat Treatment:

- **Gas quench** (3 bars) from 960 °C / 1760 °F. Sub-zero -75 °C /-103 °F. Temper at 300 °C / 572 °F

  Typical values:
  - UTS: 1350 MPa / 196 Ksi
  - 0.2 % YS: 1030 MPa / 149 Ksi
  - El: 13 %
  - KV: 110 J / 81 ft.lb

- **Oil quench** (3 bars) from 960 °C / 1760 °F. Sub-zero -75 °C /-103 °F. Temper at 300 °C / 572 °F

  Typical values:
  - UTS: 1400 MPa / 203 Ksi
  - 0.2 % YS: 1120 MPa / 162 Ksi
  - El: 13 %
  - KV: 120 J / 88 ft.lb

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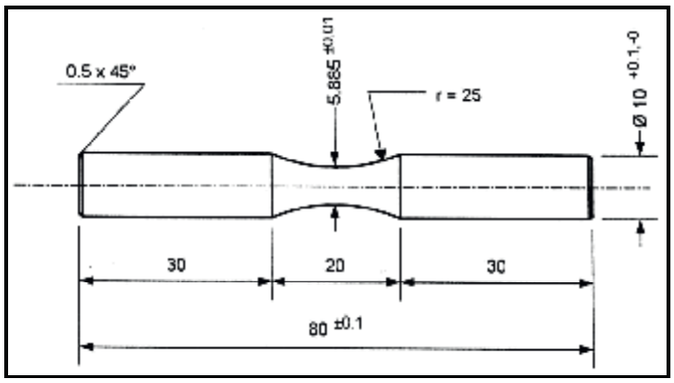
Rotative bending

R = -1
Kt = 1.035
Fatigue limit for 2.10^7 cycles,
50% chance of failure



Annealing:

- 980 °C / 1796 °F - Air cooling
- 680 °C / 1256 °F - Air cooling

Case hardening

Heat treatment to apply:

- 960 °C / 1760 °F - Gas quenching
- -75 °C / -103 °C - 2 hrs
- Tempering 250 °C / 482 °F - 2 hrs

Mechanical characteristics

Heat treated material (base metal)

- UTS: 1378 MPa / 200 Ksi
- 0.2 % YS: 1014 MPa / 147 Ksi
- Fatigue limit 2.10^7 cycles: 729 MPa / 106 Ksi

Case hardened and heat treated material

- UTS: 1347 MPa / 195 Ksi
- 0.2 % YS: 989 MPa / 143 Ksi
- Fatigue limit 2.10^7 cycles: 1093 MPa / 158 Ksi

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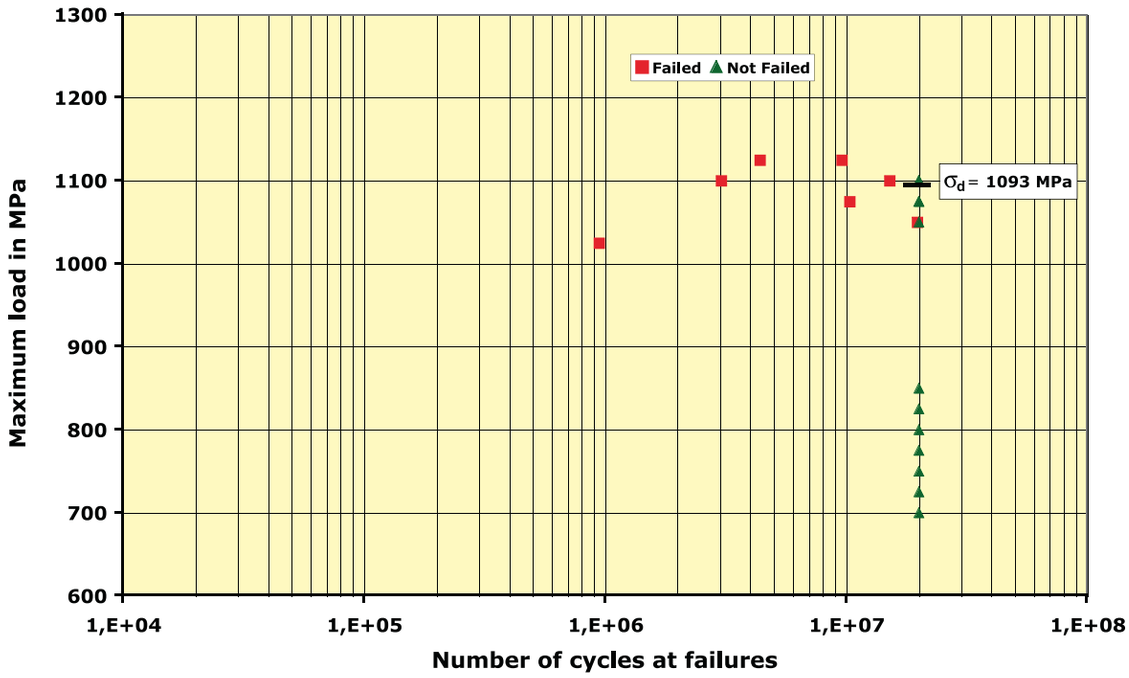
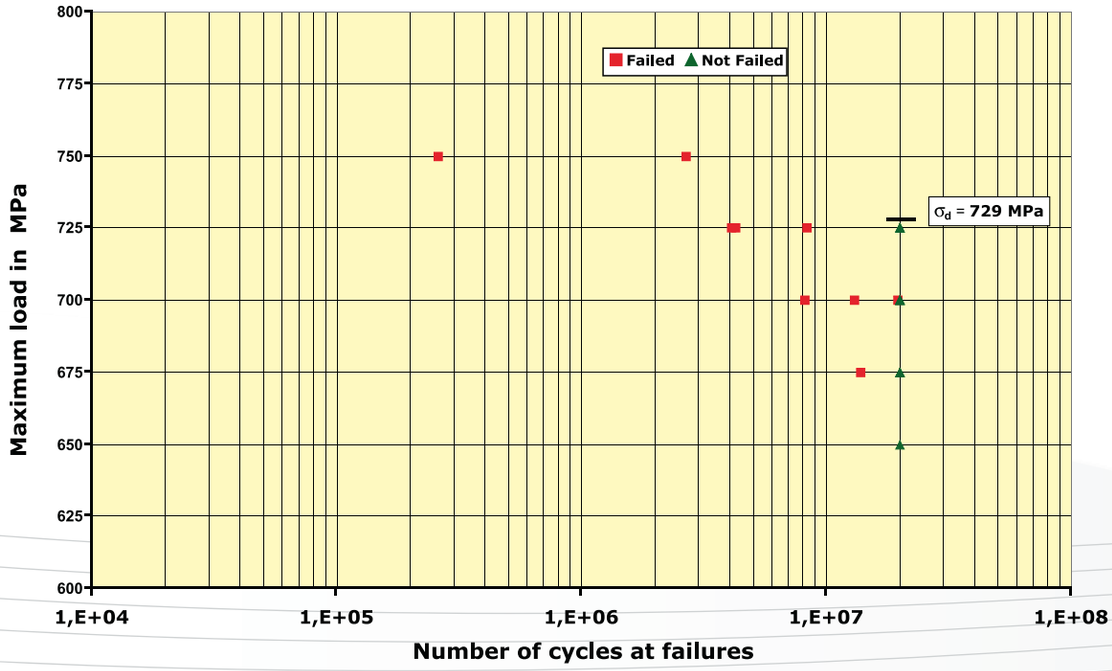
Rotative bending fatigue S/n curve - case hardened



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
Fatigue limit for 2.10^7 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)
FADC (W)	10NiCrMo13-5 9310 AMS: 6265	825°C / Oil -75°C 150°C	1150 / *467*	900 / *131*	600 / *97*	1050 / *152*
50NILYW	13MoCrNiV42-16-14 M50NIL	1100°C / Oil -75°C 3 x 540°C	1400 / *203*	1200 / *174*	750 / *109*	1075 / *156*
FADH (W)	14NiCrMo13-4 BS: S157 - 1.6657	825°C / Oil -75°C 150°C	1350 / *196*	1000 / *145*	760 / *110*	1100 / *160*
FDG (W)	20NiCrMo13 1.6660 AMS: 6492 - 6493	825°C / Oil -75°C 150°C	1450 / *210*	1100 / *160*	890 / *129*	1160 / *168*
FND (W)	15NiMoSiCr10 AMS: 6494 - 6495	960°C / Gas -75°C 250°C	1350 / *196*	1030 / *149*	729 / *106*	1093 / *158*

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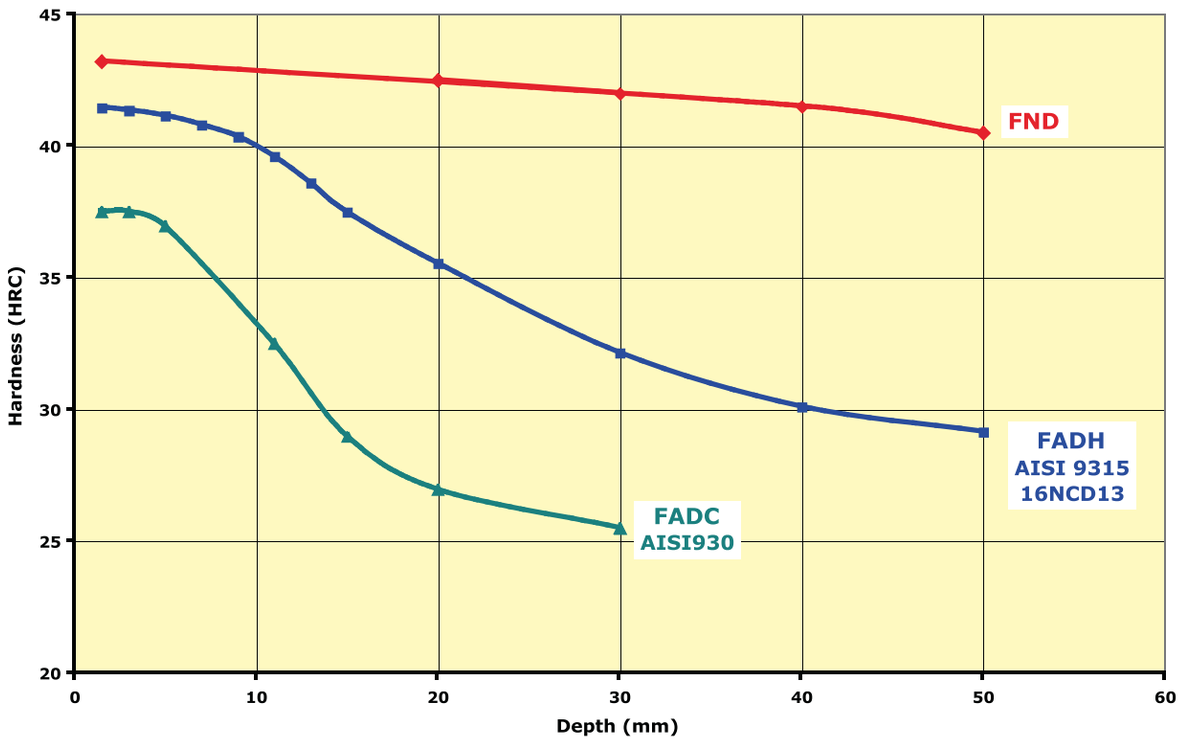
JOMINY CURVE

The Jominy curves clearly show that FND is capable of large parts and displays homogeneous properties.



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NOTES:

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Design: affinity makhesis group

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