

AUBERT&DUVAL



CX13VD (W)

X12CrNiMoV12-3

A carburizing stainless steel
for structural applications

CONTINUOUS
METALLURGICAL
INNOVATION

SPECIAL STEELS

DEVELOPMENT

RESEARCH

SERVICE

Enhancing your performance



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THE INDUSTRIAL ENVIRONMENT

Stainless steels are growing in importance due to the new regulations (Cr and Cd ban) and the need to reduce maintenance costs. They find applications in different types of markets (mechanics, aerospace, chemical...). Some applications require bearing functions. These are most often obtained through surface treatment, mainly carburizing.

AUBERT & DUVAL has developed a simple carburizing stainless solution: CX13VD(W). The grade is fully stainless with high properties (resistance and ductility). The composition and the process parameters are tightly controlled so that the grade shows good carburizing capabilities.

The grade, already widely used in the aerospace industry, offers the following advantages:

- Fully stainless,
- Simple martensitic solution,
- Easy to carburize (low pressure or gas pressure with pre-oxidation),
- High strength,
- High ductility,
- High tempering temperature (up to 300 °C).

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DESIGN OF THE GRADE

- Possibility to replace current non-stainless solutions with CX13VD(W):
 - > Classic heat treatment, i.e. classic composition (no Cobalt)
 - > Carburizing depth, structures and conditions similar to those already in place.
- A grade which can be found with different qualities (Air melted, remelted VIM - VAR).

APPLICATIONS

- Ball-screws (example: A380 horizontal stabilizer, 787 brakes),
- Injection bodies for corrosive environment,
- Shafts with parts operating in corrosive environment (sea water).

CHEMICAL COMPOSITION

| | C | Si | Mn | Cr | Ni | Mo | V | N₂ |
|------|----------|-----------|-----------|-----------|-----------|-----------|----------|----------------------|
| min. | 0.10 | ≤ 0.30 | 0.50 | 11.00 | 2.00 | 1.50 | 0.25 | 0.010 |
| max. | 0.15 | | 0.90 | 12.50 | 3.00 | 2.00 | 0.40 | 0.050 |

SPECIFICATIONS

- X12CrNiMoV12-3
- UNS: S64152
- Euro Number: 1.4933
- AMS: 5719





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COMPARISON OF DIFFERENT CASE HARDENING STEELS

| Grades | Operating temperature | C | Cr | Ni | Mo | V |
|--|-----------------------|-------------|--------------|-------------|-------------|-------------|
| FADC(W) 10NiCrMo13-5 AISI: 9310 | < 100 °C | 0.10 | 1.20 | 3.25 | 0.10 | |
| FADH(W) 14NiCrMo13-4 | < 100 °C | 0.16 | 1.00 | 3.20 | 0.25 | |
| APX(W) X17CrNi16-2 AISI: 431 | < 250 °C | 0.16 | 17.00 | 2.00 | | |
| CX13VD(W) X12CrNiMoV12-3 | < 250 °C | 0.12 | 12.00 | 2.50 | 1.60 | 0.30 |

COMPARISON OF THE CORE CHARACTERISTICS OF DIFFERENT CASE HARDENING STEELS

| Grades | Heat treatment | UTS (MPa) | 0.2% YS (MPa) | E (%) | KV (J) | K1c MPaV ^m |
|--|-----------------------------------|-------------|---------------|-----------|------------|-----------------------|
| FADC(W) 10NiCrMo13-5 AISI: 9310 | 825 °C / Oil -75 °C 150 °C | 1150 | 900 | 14 | 100 | |
| FADH(W) 14NiCrMo13-4 | 825 °C / Oil -75 °C 150 °C | 1350 | 1000 | 14 | 140 | |
| APX(W) X17CrNi16-2 AISI: 431 | 1020 °C / Oil -75 °C 250 °C | 1500 | 1080 | 13 | 30 | |
| CX13VD(W) X12CrNiMoV12-3 | 1050 °C / Oil -75 °C 250 °C | 1350 | 1000 | 13 | 130 | 130 |



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TRANSFORMATION POINTS

| | |
|------------|---------|
| γ | 1050 °C |
| Ac1 | 690 °C |
| Ac3 | 795 °C |
| Ms | 230 °C |

MACROSTRUCTURE

The segregations, as measured on the ingots, comply 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

Typical values found for the grade are well within the strictest requirements.

Typical values according to ASTM E45

| A | | B | | C | | D | |
|------|-------|------|-------|------|-------|------|-------|
| Thin | Thick | Thin | Thick | Thin | Thick | Thin | Thick |
| 1.5 | 1.0 | 1.5 | 1.0 | 1.5 | 1.0 | 1.5 | 1.0 |

Typical values according to DIN 50602

$$K1 \leq 10$$



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CARBURIZING

AUBERT & DUVAL has a long history in the technology of stainless steels carburizing.

- Development of low pressure carburizing process (> 20 years of experience)
- Applied to **APX** (X17CrNi16-2 / AISI 431) aerospace ball joint rod ends for over 20 years.

Low pressure case hardening combines several advantages for stainless steels:

- > Heating vacuum, i.e. no oxygen.
- > Use of a hydrocarbon, i.e. no CO (and no O₂).
- > Large working temperature range available.



Low pressure carburizing furnace at Aubert & Duval

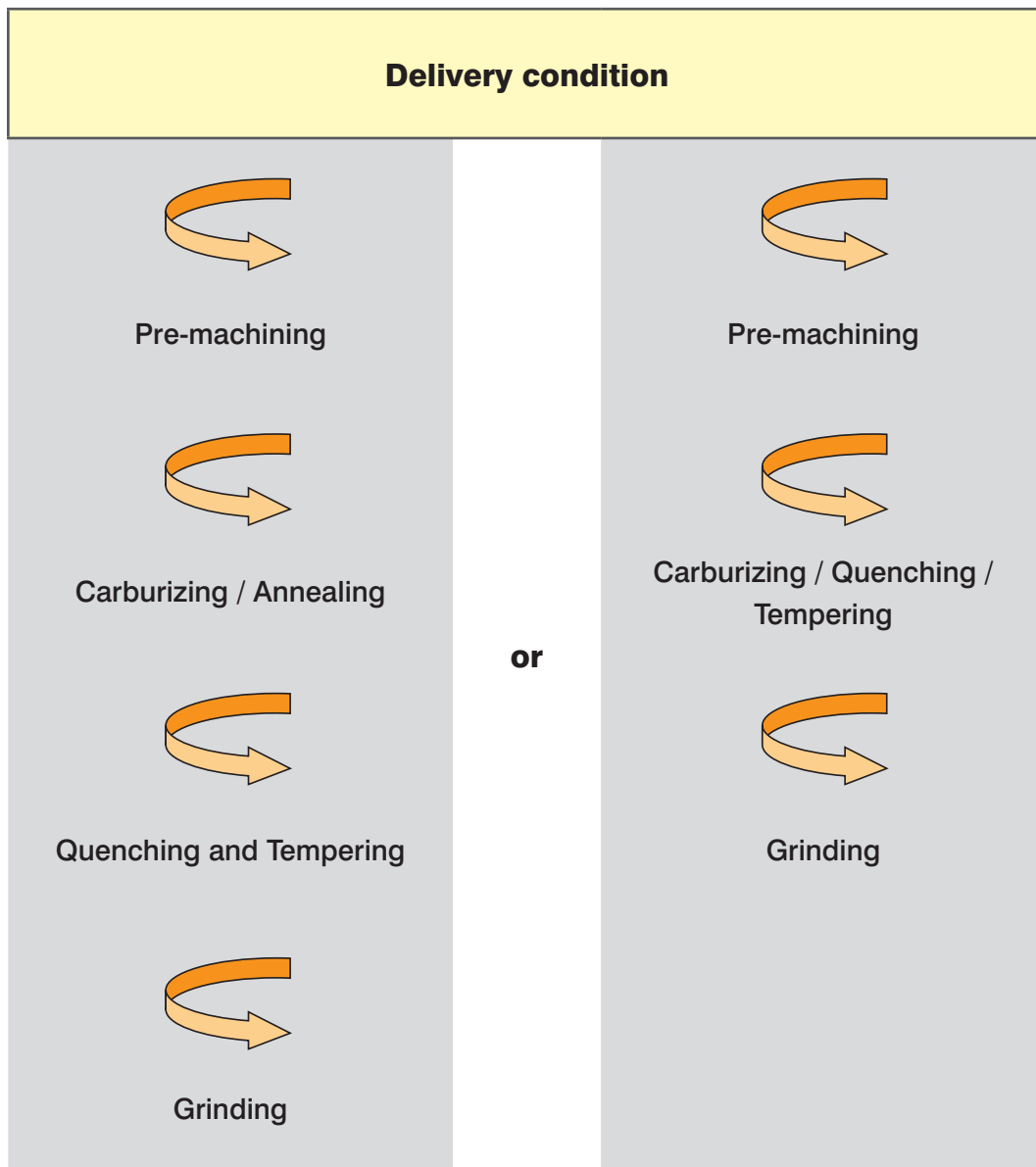
The composition of CX13VDW is optimized for ensuring a homogeneous carburizing layer. The grade can be carburized either in low pressure or air installations. This is currently done in France, UK, US, Japan, Italy and other countries.



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FABRICATION PROCESS OF THE PART:



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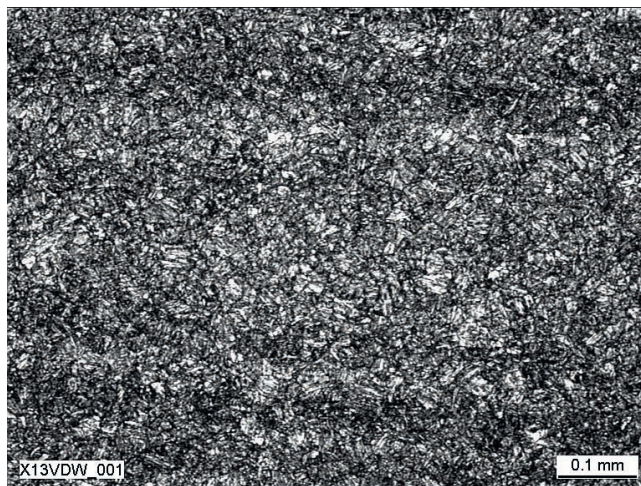
MICROGRAPHIC CHARACTERIZATION

Annealed condition

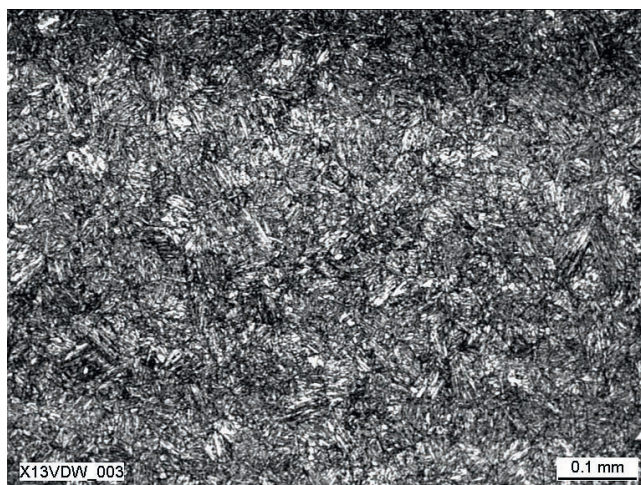
- > 830°C/550 °C - Air cooling
- > 670°C/550 °C - Air cooling

Microstructures:

- > Hardness: 255 HB



x 100



x 500

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Heat treated condition

Case Hardening

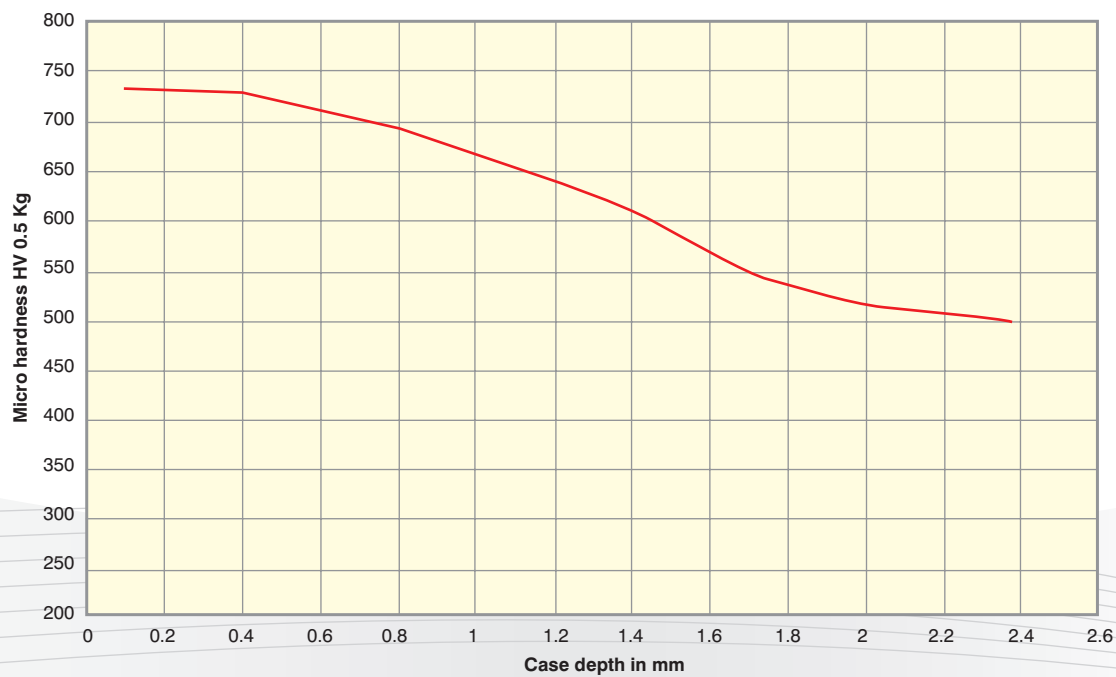
Heat treatment to apply:

- > 1050 °C - 0h30
- > Oil quenching
- > -75 °C - 2h00
- > Tempering 250 °C - 2h00

Typical aspect of the carburized structure
L direction – x 200



Case hardness profile





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MECHANICAL PROPERTIES

AMS 5719 - Tempering at 690 °C

(Minimum requirements)

- UTS: 1070 MPa
- 0.2 % YS: 896 MPa
- E (5d): 12 %
- KV: 41 J

Hardness: 341 - 375 HB
(36.6 - 40.4 HRC)

CX13VDW - Typical values

Tempering at 250 °C

- UTS: 1350 MPa
- 0.2 % YS: 1000 MPa
- E (5d): 13 %
- KV: 130 J

Tempering at 650 °C

- UTS: 1050 MPa
- 0.2 % YS: 700 MPa
- E (5d): 15 %
- KV: 140 J

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MECHANICAL PROPERTIES

Rotative bending

R = -1

Kt = 1.035

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

Annealing:

- 830°C to 550 °C - Air Cooling
- 670°C to 550 °C - Air Cooling

Case Hardening

Heat treatment to apply:

- 1050 °C - 0h30
- Oil quenching
- -75 °C - 2h00
- Tempering 250 °C - 2h00

Case depth: 1.20 mm

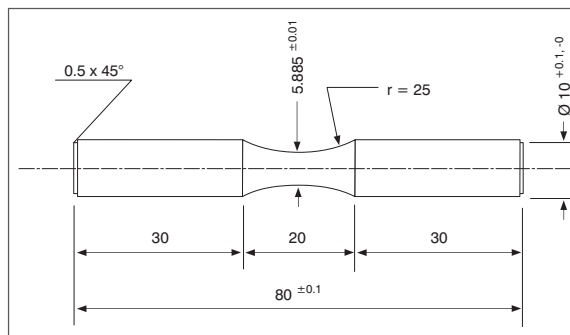
Mechanical characteristics

Heat treated material (Base Metal)

- UTS: 1345 MPa
- 0.2 % YS: 975 MPa
- Fatigue limit $2 \cdot 10^7$ cycles: 640 MPa

Case hardened and heat treated material

- UTS: 1350 MPa
- 0.2 % YS: 970 MPa
- Fatigue limit $2 \cdot 10^7$ cycles: 913 MPa





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Comparison of the fatigue limit of different surface hardenable steels

Rotative bending

R = -1

Kt = 1.035

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

| | | Heat treatment | 0.2 % YS (MPa) | UTS (MPa) | σ (MPa) |
|---|------|--|----------------|-----------|--------------------|
| Steel | | | | | |
| FADHW 14NiCrMo13-4 | Core | 825 °C Oil quench 150 °C - 2 hrs | 1000 | 1350 | 660 |
| | Case | | | | 1080 |
| Stainless steels | | | | | |
| XD15NW X40CrMoVN16-2 AMS5925 | Core | 1050 °C / Oil quench 2 x 650 °C / 2 hrs | 900 | 1200 | 640 |
| | Case | | | | Induction hardened |
| CX13VDW X12CrNiMoV12-13 | Core | 1050 °C / Oil quench -75 °C / 2 hrs 250 °C / 2 hrs | 1000 | 1350 | 640 |
| | Case | | | | DC550: 1.20 mm |

Fracture toughness

Annealing:

- 830 °C to 550 °C - Air Cooling
- 670 °C to 550 °C - Air Cooling

Case Hardening

Heat treatment to apply:

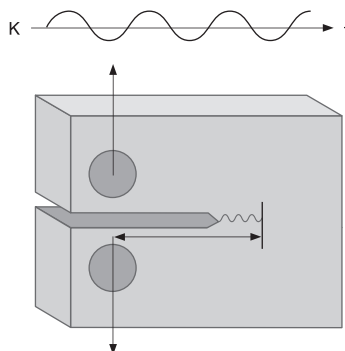
- 1050 °C - 0h30
- Oil quenching
- -75 °C - 2h00
- Tempering 250 °C - 2h00

Mechanical characteristics

- UTS: 1350 MPa
- 0.2 % YS: 970 MPa

Specification ASTM E399

| K1c (MPa√m) | CT20 | L-T | 125 |
|-------------|------|-----|-----|
| | | T-L | 120 |
| | CT40 | T-L | 140 |





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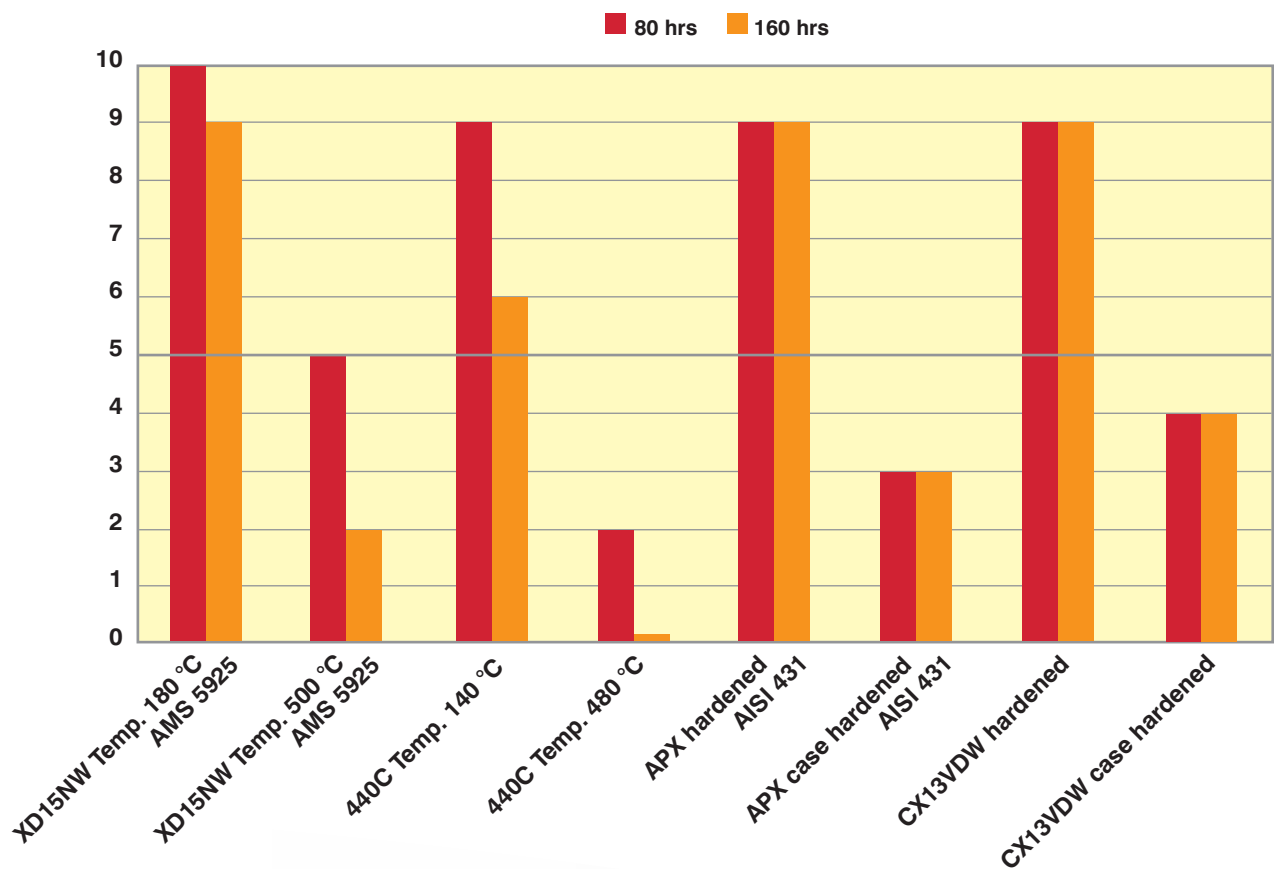
CORROSION RESISTANCE

The corrosion resistance is characterized with the following test:

- Salt spray test according to NF X 41-002

Salt spray test

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





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MACHINING

The following parameters are indicative and should be adapted to the tools, machines and parts.

Annealed condition

Turning (insert)

Roughing

- Speed: 140 m/min
- Feed: 0.25 mm/rev
- Depth: 2 mm
- Intensive lubrication.

Finishing

- Speed: 150 m/min
- Feed: 0.1 mm/rev
- Depth: 0.5 mm
- Intensive lubrication.

Milling (insert)

Roughing

- Speed: 140 m/min
- Feed: 0.025 mm/tooth
- Depth: 1 to 1.5 mm
- Intensive lubrication.

Finishing

- Speed: 150 m/min
- Feed: 0.015 mm/tooth
- Depth: 0.5 mm
- Intensive lubrication.





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