GKP™ (W - YW)
32CrMoNiV5

An innovative steel for very deep nitriding

CONTINUOUS METALLURGICAL INNOVATION
SPECIAL STEELS DEVELOPMENT
RESEARCH SERVICE

Enhancing your performance
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

<table>
<thead>
<tr>
<th>%</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>V</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>min.</td>
<td>0.29</td>
<td>-</td>
<td>0.70</td>
<td>1.10</td>
<td>0.50</td>
<td>0.90</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>max.</td>
<td>0.36</td>
<td>0.30</td>
<td>1.20</td>
<td>1.60</td>
<td>1.00</td>
<td>1.40</td>
<td>0.40</td>
<td>0.30</td>
</tr>
</tbody>
</table>

UNS: K23280
AMS 6496 (Air Melted), 6497 (Remelted), 6498 (Double Vacuum Melted)
GKP™ (W - YW)  

32CrMoNiV5

**SPECIFICATIONS**

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

**COMPARISON OF DIFFERENT STEELS**

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

COMPARISON OF THE CORE CHARACTERISTICS OF DIFFERENT STEELS

<table>
<thead>
<tr>
<th>A&amp;D Grades</th>
<th>Heat treatment</th>
<th>UTS (MPa / Ksi)</th>
<th>0.2% YS (MPa / Ksi)</th>
<th>E (%)</th>
<th>KV (J / ft.lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through Hardened steel RA50YW</td>
<td>1100°C / Gas -75°C 3 x 550°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carburized steels FADC (W - YW)</td>
<td>825°C / Oil -75°C 150°C</td>
<td>1150 / 167</td>
<td>900 / 131</td>
<td>14</td>
<td>140 / 103</td>
</tr>
<tr>
<td></td>
<td>50NILYW</td>
<td>1400 / 203</td>
<td>1200 / 174</td>
<td>15</td>
<td>12 / 9</td>
</tr>
<tr>
<td>Nitrided steels  GH4 (W - YW)</td>
<td>825°C / Oil 600°C</td>
<td>1400 / 203</td>
<td>1150 / 167</td>
<td>13</td>
<td>40 / 29</td>
</tr>
<tr>
<td></td>
<td>GKH (W - YW)</td>
<td>600°C</td>
<td>1250 / 181</td>
<td>1060 / 154</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>640°C</td>
<td>1080 / 157</td>
<td>900 / 131</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>GKP (W - YW)</td>
<td>600°C</td>
<td>1430 / 207</td>
<td>1280 / 186</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>640°C</td>
<td>1250 / 181</td>
<td>1075 / 156</td>
<td>16</td>
</tr>
</tbody>
</table>

COMPARISON OF SURFACE CHARACTERISTICS

<table>
<thead>
<tr>
<th>A&amp;D Grades</th>
<th>Heat treatment</th>
<th>Use temperature</th>
<th>Surface hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through Hardened steel RA50YW</td>
<td>1100°C / Gas -75°C 3 x 550°C</td>
<td>&lt; 450°C</td>
<td>HRC: 60 / 63</td>
</tr>
<tr>
<td>Carburized steels FADC (W - YW)</td>
<td>825°C / Oil -75°C 150°C</td>
<td>&lt; 150°C</td>
<td>HRC ≥ 60</td>
</tr>
<tr>
<td></td>
<td>50NILYW</td>
<td>&lt; 400°C</td>
<td>HRC ≥ 60</td>
</tr>
<tr>
<td>Nitrided steels  GH4 (W - YW)</td>
<td>825°C / Oil 600°C</td>
<td>&lt; 450°C</td>
<td>HV: 850</td>
</tr>
<tr>
<td></td>
<td>GKH (W - YW)</td>
<td>&lt; 450°C</td>
<td>HV: 850</td>
</tr>
<tr>
<td></td>
<td>GKP (W - YW)</td>
<td>&lt; 450°C</td>
<td>HV: 900</td>
</tr>
</tbody>
</table>

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MAIN PHYSICAL PROPERTIES

Density: 7.8

Mean coefficient of Thermal Expansion:

<table>
<thead>
<tr>
<th>Temperature range</th>
<th>10^(-6)/m/m/°C</th>
<th>10^(-6)/in/in/°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 / 100</td>
<td>11.8</td>
<td>6.55</td>
</tr>
<tr>
<td>20 / 500</td>
<td>13.6</td>
<td>7.55</td>
</tr>
</tbody>
</table>

CCT DIAGRAM

CCT/TTT - Diagram

Temperature °C

Time min

Bainite
Pearlite

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TRANSFORMATION POINTS

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ac1</td>
<td>760°C / 1400°F</td>
<td></td>
</tr>
<tr>
<td>Ac3</td>
<td>850°C / 1562°F</td>
<td></td>
</tr>
</tbody>
</table>

MACROSTRUCTURE

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

<table>
<thead>
<tr>
<th>Class</th>
<th>Condition</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Freckles</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>White spots</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>Radial segregation</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>Ring pattern</td>
<td>B</td>
</tr>
</tbody>
</table>

Macrostructure according to ASTM A 604
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MICROGRAPHIC CHARACTERIZATION

Annealed condition
Heat to 875°C / 1607°F followed by slow cooling.
Brinell hardness: 240
**GKP™ (W - YW)**

**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**

![Graph showing micro hardness (HV 0.5) vs depth (mm)]

- Depth : 0.9 mm
- Depth : 0.4 mm

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MECHANICAL CHARACTERISTICS VARIANCE WITH THE TEMPERING TEMPERATURE

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

![Graph showing mechanical characteristics variance with tempering temperature](Graph.png)
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Rotative bending
R = -1
Kt = 1.035
Polished samples
Fatigue limit for 2.10⁷ cycles, 50% chance of failure

Heat treatment:
- 940°C / 1724°F – 30 min
- Oil quenching
- Tempering 630°C / 1166°F – 2 hrs
- Nitriding:
  T: ≤ 530°C / 986°F
  Duration: ≥ 180 hrs
  Depth: 0.8 mm

Mechanical characteristics
- UTS: 1348 MPa
- 0.2 YS: 1248 MPa

- Fatigue limit 2.10⁷ cycles:
  - Base metal: 840 MPa / 122 Ksi
  - Nitriding: > 1360 MPa / 197 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 2.10^7 cycles, 50% chance of failure

<table>
<thead>
<tr>
<th>A&amp;D Grades</th>
<th>Heat treatment</th>
<th>UTS (MPa / Ksi)</th>
<th>0.2% YS (MPa / Ksi)</th>
<th>Lf core material (MPa / Ksi)</th>
<th>Lf case hardened (MPa / Ksi)</th>
<th>Case depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through Hardened steel</td>
<td>RA50YW</td>
<td>1100°C / Gas 3 x 550°C</td>
<td>HRC: 60 - 63</td>
<td>950 / 138</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Carburized steels</td>
<td>FADCW</td>
<td>825°C / Oil -75°C 150°C</td>
<td>1150 467</td>
<td>900 131</td>
<td>600 / 87</td>
<td>1050 / 152</td>
</tr>
<tr>
<td>50NILYW</td>
<td>1100°C / Oil -75°C 3 x 540°C</td>
<td>1400 203</td>
<td>1200 174</td>
<td>750 / 109</td>
<td>1075 / 156</td>
<td>DC550: 1.3 mm</td>
</tr>
<tr>
<td>Nitrided steels</td>
<td>GH4YW</td>
<td>825°C / Oil 600°C</td>
<td>1400 203</td>
<td>1150 167</td>
<td>810 / 112</td>
<td>1150 / 167</td>
</tr>
<tr>
<td>GKYHW</td>
<td>920°C / Oil</td>
<td>1250 181</td>
<td>1060 164</td>
<td>825 / 120</td>
<td>&gt; 1200 &gt; 174</td>
<td>HVACore + 100: 0.6 mm</td>
</tr>
<tr>
<td>GKPYW</td>
<td>940°C / Oil 640°C</td>
<td>1250 181</td>
<td>1075 156</td>
<td>840 / 122</td>
<td>&gt; 1330 &gt; 193</td>
<td>HVACore + 100: 0.8 mm</td>
</tr>
</tbody>
</table>

*Effect of residual stresses in nitrided layer*
SURFACE PROPERTIES

Compressive stress in a nitrided layer

![Graph showing stress vs depth](image)

**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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NOTES:

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NOTES:

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Design: affinity* ftp**
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