TECHNICAL SUPPLY CONDITIONS AND MACRO AND MICROSTRUCTURAL STANDARDS FOR ALPHA-BETA TITANIUM ALLOYS

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Introduction

The growing importance of titanium for an increasing number of applications, particularly in the chemical processing and aerospace fields, has created a need for standardisation within Europe of supply conditions for titanium products.

With this in mind, the four leading European titanium producers decided in 1972 to form a committee to pool available knowledge and experience with the aim of formulating joint standardisation proposals. The four member companies of the committee, known as the Technical Committee of European Titanium Producers (ETTC) are:

Contimet, Titanium Division of Thyssen Edelstahlwerke AG, Krefeld
Fried Krupp GmbH, Krupp Metall-und Schmiedewerke, Essen
IMI Titanium, IMI Kynoch Ltd., Birmingham

Publications

The first result of ETTC's work was the publication of "Technical Supply Conditions for Semi-Fabricated Products of Titanium and Titanium Alloys". This trilingual publication (English, French and German) sets out to define the conditions of supply of sheet and plate, round, square and rectangular bar, and fastener stock. It covers dimensions and tolerances, manufacturing processes, heat treatment, edge preparation for sheet and plate, surface condition, ultrasonic examination and frequency of chemical and mechanical testing. Standard and special conditions are listed from which an appropriate selection can be made for a given requirement. For most applications, standard conditions would suffice. It is worth noting, however, that special conditions can be not only more stringent (tighter tolerances or inspection standards) but can also be less stringent. For example, forging stock or bar for machining, not descaled (commonly called black bar) would be covered by special conditions whereas centreless ground machined bar is standard. Similarly annealing is the standard heat treatment state and solution treating and/or ageing would be covered by the special conditions...
of supply. Ultrasonic testing of plate would not be offered as standard but could be carried out as a special supply condition.

To illustrate the system which has been used, typical examples from the publication are reproduced in Figs. 1, 2 and 3.

The second ETTC publication is "Microstructural Standards for α+β Titanium Alloy Bars". Again in 3 languages, the booklet contains 81 photomicrographs of transverse and longitudinal bar structures from which limits of acceptability for Standard Aircraft Quality (STQ) and Premium Quality (PQ) can be agreed. The standards, divided into 3 parts, are based on Ti-6Al-4V but should be equally applicable to other α+β titanium alloys such as Ti-6Al-6V-2Sn and Ti-4Al-4Mo-2Sn-0.5Si. In the first part transverse microstructures (X200) of bar up to and including 100 mm diameter are presented together with proposed limits of acceptance for Standard Aircraft Quality (STQ) and Premium Quality (PQ) bar. The second part includes transverse microstructures (X100) for bar between 100 and 350 mm diameter, with tighter acceptance limits for bar less than 225 mm diameter and for Premium Quality (PQ) bar.

The third part covers longitudinal microstructures (X100) applicable only to Premium Quality (PQ) bar between 100 mm and 350 mm diameter together with proposed limits of acceptance.

Typical pages from the publication are reproduced in Figs. 4 and 5.

Future publications will include "Macrostructural Standards for α+β Titanium Alloy Bars" and "Microstructural Standards for α+β Titanium Alloy Plate".

Availability of these multinational supply conditions and microstructural standards has proved helpful to both suppliers and users of titanium throughout Europe in setting standards. For example the generation of AECMA (Association Européenne des Constructeurs de Matériel Aérospatial) specifications for titanium products for the European Aerospace Industry has also been greatly aided by using such documents as a basis for proposals.
### Standards for Alpha-Beta Alloys 2107

#### 1 Sheets and plates, standard conditions

<table>
<thead>
<tr>
<th>1.1 Dimensions</th>
<th>Sheet</th>
<th>Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤5 mm thickness</td>
<td>&gt; 5 mm thickness</td>
<td></td>
</tr>
<tr>
<td>&gt; 300 mm width</td>
<td>Width : thickness &gt; 5 : 1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.2 Manufacturing process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2.1 Cold rolled¹</td>
</tr>
<tr>
<td>1.2.2 Hot rolled</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.3 Heat treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annealed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.4 Edges</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4.1 Sheared</td>
</tr>
<tr>
<td>1.4.2 Flame cut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.5 Surface condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale-free</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.6 Out-of-flatness</th>
</tr>
</thead>
<tbody>
<tr>
<td>See Table 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.7 Thickness tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>See Table 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.8 Ultrasonic testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.9 Scope of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>For test certificates (if required by customer)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.9.1 Chemical analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 per ingot</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.9.2 Hydrogen content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 per production batch, determined on the product</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.9.3 Tensile tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 3 tests per production batch and ingot, long transverse direction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.9.4 Bend tests (sheet only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 3 transverse tests per production batch and ingot</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.10 Material properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tests in 1.9 to meet the requirements of ASTM or AECMA specifications</td>
</tr>
</tbody>
</table>

1 Generally only unalloyed titanium and Ti-2％Cu

#### 2 Sheets and plates, special conditions

Note: These conditions may be requested individually or in combination

<table>
<thead>
<tr>
<th>2.1 Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤5 mm thickness</td>
</tr>
<tr>
<td>&gt; 5 mm thickness</td>
</tr>
<tr>
<td>&gt; 300 mm width</td>
</tr>
<tr>
<td>Width : thickness &gt; 5 : 1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.2 Manufacturing process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold rolled¹</td>
</tr>
<tr>
<td>Hot rolled</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.3 Heat treatment²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution treated</td>
</tr>
<tr>
<td>Aged</td>
</tr>
<tr>
<td>Any other heat treatment condition</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.4 Edges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
</tr>
<tr>
<td>Planed or milled</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.5 Surface condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machined²</td>
</tr>
<tr>
<td>Ground or other conditioning</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.6 Out-of-flatness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special agreement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.7 Thickness tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special agreement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.8 Ultrasonic testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>See Table 8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.9 Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional inspection testing and/or release to specifications more stringent than ASTM or AECMA minimum standards for the appropriate alloy grade</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.10 Material properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>More stringent requirements</td>
</tr>
</tbody>
</table>

1 Generally unalloyed titanium and Ti-2％Cu
2 For titanium alloys only
3 Planed, milled. Not hand or swing ground

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Figure 1. Extract from ETTC Publication
Table 1: Dimensional tolerances for sheets

<table>
<thead>
<tr>
<th>Thickness up to and including</th>
<th>Hot rolled mm</th>
<th>Cold rolled mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td>±0.08</td>
<td>±0.08</td>
</tr>
<tr>
<td>1.2</td>
<td>±0.13</td>
<td>±0.19</td>
</tr>
<tr>
<td>1.6</td>
<td>±0.15</td>
<td>±0.12</td>
</tr>
<tr>
<td>2.0</td>
<td>±0.18</td>
<td>±0.13</td>
</tr>
<tr>
<td>2.5</td>
<td>±0.23</td>
<td>±0.16</td>
</tr>
<tr>
<td>3.0</td>
<td>±0.25</td>
<td>±0.18</td>
</tr>
<tr>
<td>4.0</td>
<td>±0.35</td>
<td>±0.20</td>
</tr>
<tr>
<td>5.0</td>
<td>±0.40</td>
<td>±0.25</td>
</tr>
</tbody>
</table>

Table 2: Flatness tolerances for sheets

<table>
<thead>
<tr>
<th>Material</th>
<th>Max. deviation on total length</th>
<th>Max. deviation on wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercially pure sheet</td>
<td>1%</td>
<td>&lt;0.6 mm thick</td>
</tr>
<tr>
<td>Alloy sheet</td>
<td>1%</td>
<td>&gt;0.6 mm thick</td>
</tr>
</tbody>
</table>

Table 3: Thickness tolerances for plates

<table>
<thead>
<tr>
<th>Thickness mm</th>
<th>Tolerance mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;5 ≤30</td>
<td>+2.0</td>
</tr>
<tr>
<td>&gt;30 ≤120</td>
<td>+3.0</td>
</tr>
</tbody>
</table>

Table 4: Flatness tolerances for plates

4.1 As-rolled plate

<table>
<thead>
<tr>
<th>Thickness mm</th>
<th>Deviation from flat mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;5 ≤10</td>
<td>20</td>
</tr>
<tr>
<td>&gt;10 ≤30</td>
<td>15</td>
</tr>
<tr>
<td>&gt;30 ≤120</td>
<td>10</td>
</tr>
</tbody>
</table>

4.2 Machined plate should be flat within the thickness tolerances defined in Table 3.

Table 5: Dimensional tolerances for bars from unalloyed and alloyed titanium

<table>
<thead>
<tr>
<th>Diameter mm</th>
<th>For forging mm</th>
<th>For machining mm</th>
<th>For forging mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;10 ≤18</td>
<td>1.1</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>&gt;18 ≤30</td>
<td>1.3</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>&gt;30 ≤50</td>
<td>1.6</td>
<td>0.26</td>
<td>0.25</td>
</tr>
<tr>
<td>&gt;50 ≤80</td>
<td>1.9</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>&gt;80 ≤100</td>
<td>±6</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Table 6: Dimensional tolerances for fastener stock from unalloyed and alloyed titanium

<table>
<thead>
<tr>
<th>Diameter mm</th>
<th>Standard mm</th>
<th>Special mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤3</td>
<td>0.040</td>
<td>0.025</td>
</tr>
<tr>
<td>&gt;3 ≤6</td>
<td>0.048</td>
<td>0.030</td>
</tr>
<tr>
<td>&gt;6 ≤10</td>
<td>0.058</td>
<td>0.040</td>
</tr>
<tr>
<td>&gt;10 ≤18</td>
<td>0.070</td>
<td>0.043</td>
</tr>
<tr>
<td>&gt;18 ≤20</td>
<td>0.084</td>
<td>0.052</td>
</tr>
</tbody>
</table>

Note: Out-of-roundness shall be contained within the diametral tolerances above.

Figure 2. Extract from ETTC Publication
Table 7 Ultrasonic testing conditions and acceptance levels for titanium alloy bars
Class 1 (Premium Quality), provisional

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>Test conditions</th>
<th>Acceptance levels</th>
<th>Reference defect (mm FBH)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test method</td>
<td>Type of transducer</td>
<td>Minimum Coverage</td>
</tr>
<tr>
<td>&lt;150</td>
<td>Immersion</td>
<td>Single or twin crystal</td>
<td>4</td>
</tr>
<tr>
<td>≥150 ≤250</td>
<td>Comparison of 10th back echo, contact</td>
<td>Twin crystal for contact, single crystal for immersion</td>
<td>2</td>
</tr>
<tr>
<td>≥250 ≤300</td>
<td>Contact or immersion</td>
<td>Single or twin crystal</td>
<td></td>
</tr>
</tbody>
</table>

1 Bars shall be tested to half metal depth
2 The above standards refer exclusively to alpha-beta-processed bars. For beta-processed bars the reference defects are to be agreed.
3 If reference blocks with 0.8 (1.6) mm FBH are not available, the use of blocks with 1.2 (2.0) mm FBH is permitted. In this case the acceptance level shall not exceed 45 (65)% of the reference defect amplitude.
4 FBH=flat-bottomed hole
5 As a percentage of response of reference defect amplitude
6 If length ≥ 2 mm or distance apart ≤ 25 mm

Table 8 Ultrasonic testing conditions and acceptance levels for titanium and titanium alloy plates
Class 2 (Aircraft Quality)

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Test conditions</th>
<th>Acceptance levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test method1</td>
<td>Type of transducer</td>
</tr>
<tr>
<td>&gt;5 ≤12</td>
<td>Comparison of 10th back echo, contact</td>
<td>Twin crystal for contact, single crystal for immersion</td>
</tr>
<tr>
<td>&gt;12 ≤20</td>
<td>Contact or immersion</td>
<td>Single or twin crystal</td>
</tr>
<tr>
<td>≥20 ≤100</td>
<td>Contact or immersion</td>
<td>Contact twin crystal one side 100%, Immersion one side 100%</td>
</tr>
</tbody>
</table>

1 In case of disagreement, immersion testing is predominant
2 FBH=flat-bottomed hole
3 As a percentage of response of reference defect

Figure 3. Extract from ETTC Publication
Figure 4. Extract from Publication ETTC 2.
STANDARDS FOR ALPHA-BETA ALLOYS

Figure 5. Extract from Publication ETTC 2.