INVESTIGATION AND EXPERIMENTATION IN THE USE OF TITANIUM AS A STRUCTURAL MATERIAL FOR HYDROMETALLURGICAL APPARATUS

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Foreign Technology Division
Wright-Patterson Air Force Base, Ohio
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Translation

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INVESTIGATION AND EXPERIMENTATION IN THE USE OF TITANIUM AS A STRUCTURAL MATERIAL FOR HYDROMETALLURGICAL APPARATUS

V. B. Zhilkin

The high aggressiveness of the technological media with respect to the majority of structural materials due to the simultaneous presence of sulphates and chlorides in them of metals, dissolved gases (oxygen, chlorine, sulphur dioxide), solid particles of precipitants and residue, as well as increased temperatures of up to 80° (Table 1) is a specific feature of hydrometallurgical production of nickel and cobalt. In these media, as extended industrial testing and investigation disclosed, all stainless steels and alloys, the majority of synthetic polymers (capron, polyethylene, vinyl plastic, various brands of resin), wood cellulose, natural and certain synthetic rubbers (capron, chlorine, etc.) are unstable. Stainless steels, which are the basic design material for the majority of hydrometallurgical and chemical production devices, are the most susceptible to corrosion deterioration under these conditions.

The corrosion resistance of stainless steels (brands EI401, EI402, EI403, EYalT, Kh23N, Kh55N), as well as nichrome, nickel, and cupronickel in a synthetic solution corresponding to the composition of industrial anolyte was studied. All these materials proved to be unstable. Kh23N23M2, EYalT, Kh23N steels, Hastelloy

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alloy B, and electrolytic copper were tested in industrial media. They also deteriorated rapidly in anolyte, and in a bath after removal of iron, i.e., in the most aggressive media with regard to the metallic structural material media of the nickel electrolysis plant. Later on, multifaceted tests were conducted on Kh23N28M3D3T and Kh18N12M2T steels, as well as on titanium for the purpose of determining their suitability and quality as a structural material for manufacturing centrifuges. Under laboratory conditions the samples were tested by boiling in a solution after removal from iron, and then under production conditions — in a flowing anolyte for 110-120 hours. It was clear that titanium has high resistance whereas the stainless steels experienced strongly expressed localized corrosion.

Table 1. Characteristics of the basic technological media for the hydrometallurgical production of nickel.

<table>
<thead>
<tr>
<th>Medium</th>
<th>Solid phase content, g/m³</th>
<th>Liquid phase characteristics: T, °C; pH</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Anolyte</td>
<td>Practically none</td>
<td>70; 2.5*</td>
<td>-</td>
</tr>
<tr>
<td>2. Ferrous</td>
<td>≤2</td>
<td>70; 3.5</td>
<td>The suspension is aerated and contains active chlorine compounds</td>
</tr>
<tr>
<td>sinter cake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>suspension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Cement</td>
<td>≤1</td>
<td>70; 2.5</td>
<td>The suspension is mixed hydrodynamically and contains copper and nickel metallic particles</td>
</tr>
<tr>
<td>copper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>suspension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Cobalt</td>
<td>≤4</td>
<td>70; 4.0</td>
<td>The suspension is aerated and contains active chlorine compounds</td>
</tr>
<tr>
<td>sinter cake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>suspension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Catholyte</td>
<td>Prohibited</td>
<td>70; 2.6</td>
<td>-</td>
</tr>
</tbody>
</table>

* - 70 g/ℓ of nickel.

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Below are some of the results of testing titanium alloys for corrosion in industrial media and under laboratory conditions. The tests were conducted by screening in flowing media (see Table 1), directly in the technological apparatus, samples of titanium alloys belonging to different alloying systems. The samples were prepared from various semifinished products - sheets, forged rods, pipes, casts, foils with different kinds of technological treatment.

Welded samples were also tested. Corrosion control was accomplished a) by internal features (visually); b) by changing the weight (the absence of signs of localized corrosion was the basis for calculating the deep-seated indicator); c) by changing the mechanical properties for exposing the intercrystalline corrosion (for testing discontinuous samples and Menage samples were used). The test time for the samples was not less than 1000 hours. All the samples proved to be stable - stability, according to GOST 5272-50 [ГОСТ = ГОСТ = All-Union State Standard], was 1 point. The test results, given in Table 2, permitted the following conclusions to be drawn:

1. In conditions of basic technological media of a nickel electrolysis plant, all titanium samples tested were found to be in the stable, passive state and are completely stable (1 point on the GOST 5272-50 scale).

2. All alloys tested showed no disposition to intercrystalline corrosion.

3. The strength of weld seams is equivalent to the strength of the base metal.

4. Technological working (casting, hot deformation, mechanical treatment) does not reduce the corrosion resistance of titanium alloys under test conditions.
<table>
<thead>
<tr>
<th>Brand or alloy system</th>
<th>Chemical composition, %</th>
<th>Sample characteristics</th>
<th>Proposed purpose of the alloy, test purpose</th>
<th>Test size (notching medium according to Table 1)</th>
<th>Test time, hours</th>
<th>Corrosion inspection method</th>
<th>Corrosion test results</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>VTI</td>
<td>Technical titanium</td>
<td>Ingots, rods, sheets, pipes, welded samples</td>
<td>Basic structural material for manufactured apparatus</td>
<td>1, 2, 3, 8</td>
<td>1000-4000</td>
<td>Without changes</td>
<td>0.001</td>
<td>Not observed***</td>
</tr>
<tr>
<td>OT-1</td>
<td>The same</td>
<td>Rods, sheets</td>
<td>The same, comparison with VT1</td>
<td>1</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-3</td>
<td>&lt;0.8</td>
<td>Rods, forgings</td>
<td>Comparison with VT1</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-EL-8</td>
<td>&lt;0.8</td>
<td>Rods, forgings</td>
<td>Comparison with VT2</td>
<td>1</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>2041</td>
<td>&lt;0.8</td>
<td>Sheets, rods</td>
<td>Production of heat exchange and other pipe apparatus</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-1</td>
<td>0.8</td>
<td>Sheets, rods</td>
<td>Comparison with VT1</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-3</td>
<td>0.8</td>
<td>Sheets, forgings</td>
<td>Comparison with VT1</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-1</td>
<td>1.5</td>
<td>Sheets, forgings</td>
<td>Comparison with VT1</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-3</td>
<td>1.5</td>
<td>Sheets, rods</td>
<td>Comparison with VT1</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-1</td>
<td>1.5</td>
<td>Sheets, forgings</td>
<td>Comparison with VT2</td>
<td>1</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-3</td>
<td>1.5</td>
<td>Sheets, forgings</td>
<td>Comparison with VT2</td>
<td>1</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>2041</td>
<td>2.5</td>
<td>Sheets, rods</td>
<td>Production of heat exchange and other pipe apparatus</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-1</td>
<td>2.5</td>
<td>Sheets, rods</td>
<td>Comparison with VT1</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-3</td>
<td>2.5</td>
<td>Sheets, forgings</td>
<td>Comparison with VT1</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>2041</td>
<td>3.0</td>
<td>Sheets, rods</td>
<td>Production of heat exchange and other pipe apparatus</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-1</td>
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<td>Comparison with VT1</td>
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<td>1000</td>
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<td>Not observed</td>
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</tr>
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<td>OT-3</td>
<td>3.5</td>
<td>Sheets, rods</td>
<td>Production of heat exchange and other pipe apparatus</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>2041</td>
<td>4.0</td>
<td>Sheets, rods</td>
<td>Production of heat exchange and other pipe apparatus</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>OT-1</td>
<td>4.0</td>
<td>Sheets, forgings</td>
<td>Comparison with VT1</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
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<td>Not observed</td>
</tr>
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<td>Sheets, rods</td>
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<td>Sheets, rods</td>
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<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
<tr>
<td>2041</td>
<td>5.0</td>
<td>Sheets, rods</td>
<td>Production of heat exchange and other pipe apparatus</td>
<td>1, 2, 3, 8</td>
<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
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<td>1000</td>
<td>The same</td>
<td>0.001</td>
<td>Not observed</td>
</tr>
</tbody>
</table>

For discontinuous sheet samples. *On manganese samples from rods or ingots. **On those and other samples.

E: An oxygen content of up to 25.

F: An oxygen content of more than 25.

"e"-alloys: A stabilizer of up to 25.

"f"-alloys: A stabilizer of more than 25.

Table 1. Results of testing titanium alloys for corrosion under working conditions.

**FTN-86-79**
5. For manufacturing technological apparatus - pumps, the locking conduit armature, filters, as well as for parts and subassemblies in regulation-measuring apparatus, which function under test conditions, it is recommended that we use technical titanium VT1 brand) since it is sufficiently strong, the most technological, unique, and feasible for economic representations of titanium alloy.

6. Using melted alloys, alloyed with aluminum (VT5) and aluminum and silicon (VT11) is recommended for improving the melt properties. It is advisable that the preparation of the melt-formed parts of the equipment be determined by structural requirements and economic feasibility.

7. Using thermal resistant VT14, VT15, and VT16 alloys in the strong structural elements (mounting parts), in KIP instrument parts and automatics (diaphragms and other elements), as well as in friction subassemblies is recommended.