PRODUCTION OF INDUSTRIAL INGOTS OF THE INTERMETALLIC VTI-4 ALLOY USING VACUUM ARC AND SKULL MELTS

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JSC «Chepetsky Mechanical Plant» is a part of TVEL Corporation. It's the enterprise of full cycle of Zirconium fabrication from raw materials to products for the nuclear industry. Also it's well known for the production of:

- Uranium;
- Calcium;
- Niobium;
- Zirconium dioxide and its articles;
- Superconducting materials.

Within diversification the manufacturing of
- Titanium alloy and
- Hafnium items
were developed and launched into production.
## Composition of VTI-4 alloy

<table>
<thead>
<tr>
<th>Elements</th>
<th>Al</th>
<th>Nb</th>
<th>Zr</th>
<th>Mo</th>
<th>V</th>
<th>Si</th>
<th>O</th>
<th>N</th>
<th>C</th>
<th>Sum of other impurities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>10-12</td>
<td>38-42</td>
<td>1-1,5</td>
<td>0,5-1,0</td>
<td>0,5-1,0</td>
<td>0,1-0,25</td>
<td>≤ 0,08</td>
<td>≤ 0,03</td>
<td>≤ 0,03</td>
<td>≤ 0,2</td>
</tr>
</tbody>
</table>
# Large-scaled Ingots

<table>
<thead>
<tr>
<th>Diameter, mm</th>
<th>Ingot</th>
<th>Estimated weight, kg</th>
<th>Melting scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>360</td>
<td>No. 1</td>
<td>490</td>
<td>3 vacuum arc remelting</td>
</tr>
<tr>
<td></td>
<td>No. 2</td>
<td>630</td>
<td>2 vacuum arc remelting + 1 vacuum arc skull remelting</td>
</tr>
</tbody>
</table>
Composition of the Burden

Materials

Zr

Ti sponge

Al

Si

Master alloys

Nb-Ti

Al-Mo-V-Ti

V-Al
Briquettes

Vertical hydraulic press

Alloying components on the lateral surface
Welding of electrodes

Electron beam unit

Welded seam
Melting furnaces

Vacuum arc furnace

Vacuum arc scull furnace
Ingot of the 1 VAR

Ingot

Lateral surface

Thin cracks at the top end
Schull ingot

Ingot without a crown

Lateral surface

Cracks near the top end
Ingot of the 3 VAR

Ingot after unloading

Lateral surface
Ingot No.2
Ø 360 mm
after turning
### Chemical Composition of 3 VAR Ingots, wt.%

<table>
<thead>
<tr>
<th>Ingot (scheme)</th>
<th>Position</th>
<th>Al</th>
<th>Nb</th>
<th>Zr</th>
<th>Mo</th>
<th>V</th>
<th>Si</th>
<th>O</th>
<th>N</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Requirements</td>
<td>10-12</td>
<td>38-42</td>
<td>1-1,5</td>
<td>0,5-1,0</td>
<td>0,5-1</td>
<td>0,1-0,25</td>
<td>≤ 0,08</td>
<td>≤ 0,03</td>
<td>≤ 0,03</td>
</tr>
<tr>
<td>No.1 (3 VAR)</td>
<td>Top end</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,055</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Belt No.1</td>
<td>11,88</td>
<td>40,91</td>
<td>1,52</td>
<td>0,86</td>
<td>0,80</td>
<td>0,14</td>
<td>-</td>
<td>0,0070</td>
<td>0,0120</td>
</tr>
<tr>
<td></td>
<td>Belt No.2</td>
<td>11,77</td>
<td>41,26</td>
<td>1,49</td>
<td>0,87</td>
<td>0,80</td>
<td>0,14</td>
<td>-</td>
<td>0,0056</td>
<td>0,0092</td>
</tr>
<tr>
<td></td>
<td>Belt No.3</td>
<td>11,29</td>
<td>42,21</td>
<td>1,45</td>
<td>0,85</td>
<td>0,77</td>
<td>0,13</td>
<td>-</td>
<td>0,0061</td>
<td>0,0095</td>
</tr>
<tr>
<td></td>
<td>Bottom end</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,053</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>11,65</td>
<td>41,46</td>
<td>1,49</td>
<td>0,86</td>
<td>0,79</td>
<td>0,14</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>No.2 (2 VAR+ 1 VASR)</td>
<td>Top end</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,052</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Belt No.1</td>
<td>12,12</td>
<td>40,86</td>
<td>1,25</td>
<td>0,9</td>
<td>0,84</td>
<td>0,14</td>
<td>-</td>
<td>0,0081</td>
<td>0,018</td>
</tr>
<tr>
<td></td>
<td>Belt No.2</td>
<td>11,94</td>
<td>41,51</td>
<td>1,28</td>
<td>0,89</td>
<td>0,83</td>
<td>0,13</td>
<td>-</td>
<td>0,0100</td>
<td>0,013</td>
</tr>
<tr>
<td></td>
<td>Belt No.3</td>
<td>11,87</td>
<td>41,32</td>
<td>1,27</td>
<td>0,89</td>
<td>0,83</td>
<td>0,13</td>
<td>-</td>
<td>0,0099</td>
<td>0,013</td>
</tr>
<tr>
<td></td>
<td>Bottom end</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,048</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>11,98</td>
<td>41,23</td>
<td>1,27</td>
<td>0,89</td>
<td>0,83</td>
<td>0,13</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

A. Alexandrov, Leading Research Engineer

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### Statistical Analysis of 3 VAR Ingots

<table>
<thead>
<tr>
<th>Element</th>
<th>Ingot No.1 (scheme 3 VAR)</th>
<th>Ingot No.2 (scheme 2 VAR + 1 VASR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range, wt.%</td>
<td>Standard deviation, wt.%</td>
</tr>
<tr>
<td>Al</td>
<td>0.59</td>
<td>0.31</td>
</tr>
<tr>
<td>Nb</td>
<td>1.30</td>
<td>0.67</td>
</tr>
<tr>
<td>Zr</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>V</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Mo</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Si</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Statistical Analysis of 3 VAR Ingots

- Standard deviation
- Coefficient of variation

Alloying elements:
- Al
- Nb
- Zr
- V
- Mo
- Si

Graphs showing:
- Ingots No.1 (3 ВДП)
- Ingots No.2 (2 ВДП+1 ВДГП)
1 Two large-sized industrial triple remelted ingots of VTI-4 alloy were manufactured in JSC «Chepetsky Mechanical Plant»: the first - with the estimated weight of 490 kg with use of only vacuum arc remelting, the second - with the estimated weight of 630 kg with carrying out one remelting in the vacuum arc skull furnace.

2 The chemical composition of ingots corresponded to the established requirements.

3 The ingots have a uniform distribution of the alloying elements along their height. An ingot obtained with the use of skull melting has a more homogeneous distribution in comparison with an ingot of only VAR.

4 It is necessary to collect data on a series of melted ingots.

4 It is planned to implement a complex of works on examination of metal quality in an ingot volume and the analysis of its behavior in the deformation processing.
Contact

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Thank you for your attention!