Material Choice for the Vacuum Window at the Exit of BTM
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CURRENT WINDOW

Thin circular sheet of Stainless Steel 316L of 0.05 mm thickness and 200 mm diameter

Located in the BTM extraction line, at the end of the vacuum chamber upstream of the cavity of the dump

Drawing from: 07.PSB.IHENS.0031.0, 07.PSB.IHENS.0363.3
PROPOSED WINDOWS

Considering the higher intensity of the beam and great stresses caused by atmospheric pressure, **Ti6Al4V** has been selected as a material for the window. This Titanium alloy has:

- Very good mechanical properties and a lower density (that means lower energy deposition) respect to stainless steel 316L
- Mechanical resistance better than other material with lower density (e.g. Beryllium, Aluminum or Glassy Carbon)
- Good resistance at high temperature and not problem of compromising the vacuum.

In the study two different configurations for the new window have been considered, both composed by a circular sheet of Ti6Al4V:

- 0.05 mm thickness 200 mm diameter
- 0.1 mm thickness 200 mm diameter
In the model all the material properties were considered temperature dependent.
Beam Parameters for Design

<table>
<thead>
<tr>
<th>Parameters</th>
<th>NORMGPS</th>
<th>LHC25ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max beam Intensity</td>
<td>1E14 particles per pulse</td>
<td>2,1E13 particles per pulse</td>
</tr>
<tr>
<td>Beam energy</td>
<td>2 GeV</td>
<td>2 GeV</td>
</tr>
<tr>
<td>Pulse Period</td>
<td>2.4s (1.2s per cycle but dumped one out of two cycles)</td>
<td>3s (0.9 s per cycle plus 1.2 cool-down cycles)</td>
</tr>
<tr>
<td>Pulse length</td>
<td>940 ns</td>
<td>2715ns</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>4 (2.5E13 p per bunch)</td>
<td>4 bunches plus 2 bunches 900ms later (3.5E12 p per each bunches)</td>
</tr>
<tr>
<td>Bunch spacing</td>
<td>260ns (160ns full bunch 100ns between bunches)</td>
<td>507ns (180ns full bunch 327ns between bunches)</td>
</tr>
</tbody>
</table>

The analyses were performed for two most critical types of beams.

The maximum number of particles per pulse takes into account a margin of 30%.

Main source: W. Bartmann, B. Mikulec, “PS BOOSTER DUMP UPGRADE”, EDMS PBU-T-ES-0002
FE ANALYSES

• The stresses are generated mostly by the atmospheric pressure.

• The rise of the temperature is due to the interaction between the proton beam and the window.

• For the estimation of temperatures and stresses in operation, a separated physics simulation has been performed (conservative approach).
Average temperatures reached at steady state

Temperatures profiles at the peak after one pulse

The worst case for every possibility is with the NORMGPS beam

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Ti 6Al 4V</td>
<td>0,1</td>
<td>131</td>
<td>21</td>
<td>152</td>
</tr>
<tr>
<td>Ti 6Al 4V</td>
<td>0,05</td>
<td>102</td>
<td>20</td>
<td>122</td>
</tr>
<tr>
<td>Stainless Steel 316L</td>
<td>0,05</td>
<td>121</td>
<td>23</td>
<td>144</td>
</tr>
</tbody>
</table>
The static stresses generated by the atmospheric pressure are tensile. They are high in the centre and in the perimetral region.

<table>
<thead>
<tr>
<th>Window</th>
<th>Equivalent stress at the centre [MPa]</th>
<th>Equivalent stress at the perimeter [MPa]</th>
<th>Maximum displacement [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti 6Al 4V 0.1mm</td>
<td>448</td>
<td>368</td>
<td>6.8</td>
</tr>
<tr>
<td>Ti 6Al 4V 0.05mm</td>
<td>742</td>
<td>515</td>
<td>8.3</td>
</tr>
<tr>
<td>316L 0.05mm</td>
<td>397</td>
<td>302</td>
<td>10.7</td>
</tr>
</tbody>
</table>

Stresses without the beam. The thermal expansion due to the beam load generates compressive stresses at the centre and consequently tends to decrease the stresses in the area. Anyway, there is a strong correlation between the temperature and the material strength, which drops with the increase of it. Therefore the centre remains a critical part being the region with highest temperature.
The atmospheric pressure gives the fundamental stress contribution, which does not change considerably with the new beam parameters, while the temperature increases significantly with a remarkable reduction of strength.

For the Titanium windows stresses are lower than the Yield Stress, so the material works in the linear elastic region without plastic deformation.
The equivalent stress is higher than the yield stress and lower than the tensile strength: the material does not remain in the linear elastic region and experiences plastic deformation.

Due to dynamic nature of the thermal load, the real stress can be higher, provoking material failure and breaking the vacuum tightness.
CONCLUSION

The current window has a high risk of failure caused by the combination of high stresses and elevated temperature due to the exposition to the beam. It will be much safer to use a new window with a different material and higher thickness.

The final proposal is a window made of Ti 6Al 4V, with 0.1 mm thickness:

• higher thickness is much safer, reduces the stresses and it is advantageous in terms of workability and availability from the supplier.

• Lower density is better in terms of radiological activation, this simplifies interventions in the area by reducing the dose rate.
ASSEMBLY

The window design foreseen for the new device is the one used for the titanium window for the TT41.

It includes a window support made of Titanium and a standard retaining flange.

The stresses applied to the window during the assembly are the same compared to the stresses originated by assembly normally used for other windows.

Drawing from: SPSVWG__0002
Thank you for your attention