eRMC Mechanical Measurements
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28/02/2020
Outline

1. Instrumentation overview
2. Mechanical results over the structure life time
3. Powering tests
4. Conclusion
Instrumentation overview

<table>
<thead>
<tr>
<th>Part</th>
<th>Nr &amp; Directions</th>
<th>Bridge Configuration</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHELL</td>
<td>10 (Z) 10 (Θ)</td>
<td>Double quarter bridge (active SG + compensator)</td>
<td>Cr–Ni / Polyimide HBM LC13-6/350</td>
</tr>
<tr>
<td>COILS</td>
<td>6 (Z) 6 (Θ)</td>
<td>Quarter bridges + compensator</td>
<td></td>
</tr>
<tr>
<td>RODS</td>
<td>4 (Z)</td>
<td>SG full bridge</td>
<td></td>
</tr>
</tbody>
</table>
## Instrumentation overview

<table>
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<th>Bridge Configuration</th>
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</thead>
<tbody>
<tr>
<td>COILS</td>
<td>6 (Z) 6 (θ)</td>
<td>Quarter bridges + thermal and MF compensator</td>
<td>Cr – Ni / Polyimide HBM LC11-6/350</td>
</tr>
</tbody>
</table>

**Bi-axial strain measurements without bending compensation**
Mechanical results over the magnet life time

- Strain relaxation during the first thermal cycle (around 30%) and stable behavior after;
- Final delta strain during cool down fits with FEA model.
After loading
On the Insert RT
In the cryostat RT
1.9 K
RT
4.2 K
RT
Checking RT

Low coil strain values can be explained by the instrumentation (1/4 bridge)
Mechanical results over the magnet lifetime

**eRMC - Rods - Longitudinal Stress**

**Mechanical Measurements Lab** eRMC results

2/28/2020
Powering tests

- Preliminary analysis, post-processing still in progress;
- Focus on transversal strain measurements.
Powering tests – Mechanical response

Mechanical response of the structure during a quench up to 13.27 kA @ 4.5K:

- **Delta strain**: 6 MPa
- **Absolute strain**: 7 MPa
- **12.4 kA / 15 T**
- **7 MPa**
Powering tests – Mechanical response

Mechanical response of the structure during the training @1.9 K:

<table>
<thead>
<tr>
<th>ΔTraining</th>
<th>με</th>
<th>MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔTraining</td>
<td>-57</td>
<td>-6</td>
</tr>
<tr>
<td>Δjump (Q17 → Q18)</td>
<td>-33</td>
<td>-3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ΔTraining</th>
<th>με</th>
<th>MPa</th>
<th>kN/rod</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔTraining</td>
<td>17</td>
<td>3.6</td>
<td>11.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FEA</th>
<th>Avg SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>kN</td>
<td>%fem</td>
</tr>
<tr>
<td>Target CD</td>
<td>296</td>
</tr>
<tr>
<td>Target 16 T</td>
<td>316</td>
</tr>
</tbody>
</table>

2/28/2020
Conclusion

Shell :
✓ Despite a strain relaxation during the first thermal cycle, the FEA model fit well with the mechanical measurements;
✓ During powering, a small stress relaxation is visible (6 MPa) and a slope change is observed around 12.4 kA;

Coils :
✓ Strain values are quite low according to FEA : The coil is probably still loaded but measurements can be affected by the bending or torsion effect;

Rods :
✓ Nice fitting between FEA and measurements;
✓ During powering, a small stress increase is visible (4 MPa); 10% of the axial Lorentz forces in the rods.
Next steps (Instrumentation)

Mechanical instrumentation update for RMM configuration:

- Strain values are quite low on the pole and probably impacted by compression, bending and maybe torsion effects;
- Top and bottom faces of RMM coil need to be instrumented;
- Optical strain fibers (200 µm) will be used for RMM coil, keeping electrical strain gauges: Integration is in progress...
Thank you!

Questions?
Nomenclature

Measurement piece: Shell, Coil or Rod

Side on the Shell: 1 or 2
The coil number: 1 or 2
The rod number: 1, 2, 3 or 4

Location of the strain gauge:
CS: Connection Side
NCS: Non Connection Side
M: Middle
CW: ClockWise
ACW: Counter ClockWise
R: Right
L: Left

Direction of the measurement:
T: Transversal
Z: Longitudinal (Along Z axis)
Instrumentation overview

MX840 for SG reading

MX1615 for SG reading

FS22 for FBG reading

Text files created after each quench

SM18 Test Server

Catman files
Continuous storage

Mechlab Server

Electrical Strain Gauge
Tracked wavelength of FBG
Calculated strain from FBG
Current
Timing (50ms through NTP)
Fs at 1Hz up to 1 kHz
Assembly process – 19th December 2019
Assembly process – 19th December 2019

[Diagram showing various measurements and graphs related to assembly process.]