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Mechanical Behaviour of the HL-LHC Beam Screen during a Quench Test Campaign of the MQXF Short Model Magnet

HiLumi HL-LHC PROJECT

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Context

In the framework of the High-Luminosity Large Hadron Collider (HL-LHC) project, a complex assembly, known as the beam screen, will be installed in the aperture of the Nb_3Sn HL-LHC triplet magnets (MQXF) nearby the ATLAS and CMS experiments. The beam screen is an octagonally shaped pipe ensuring that the vacuum conditions, required for the stability of the beam, are met. It also shields via tungsten-based blocks the 1.9 K magnet cryogenic system from the heat loads and damage to the magnet coils that would otherwise be induced by the highly penetrating collision debris.

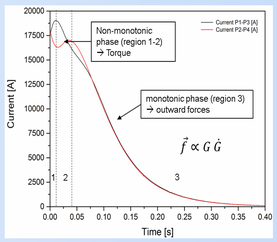
Problem

A magnet quench is a potential failure scenario for the beam screen as high intensity currents and forces are induced in the electrically conductive components of the assembly.

Objective

A dedicated test campaign has been conducted at the CERN's magnet test station in October 2018 to assess the effects of quenches on the beam screen inserted in the MQXF-4b short model magnet.

Expected behavior



Ultimate current discharge

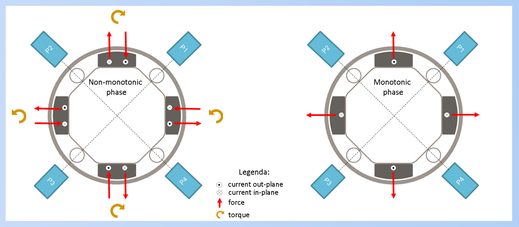
The distribution of Lorentz forces depend on the magnet protection system which is composed of Quench Heaters (QHs) and the Coupling-Loss Induced Quench (CLIQ) unit.

There are two phases in the discharge of the magnet: non monotonic and monotonic.

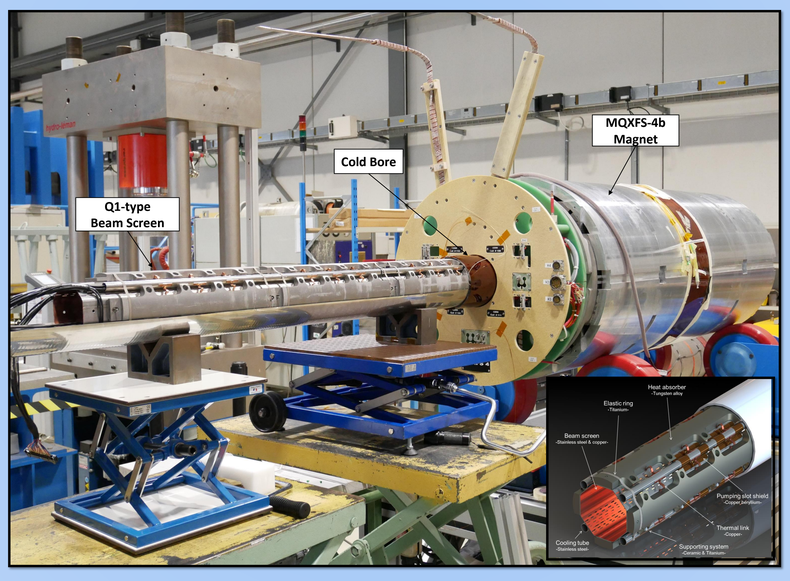
Non-monotonic phase
Torque

Monotonic phase
Outward force

Force distribution



Force and current distribution during the current discharges

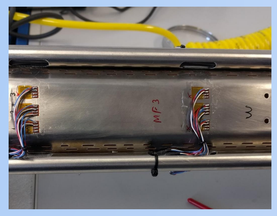


Instrumentation

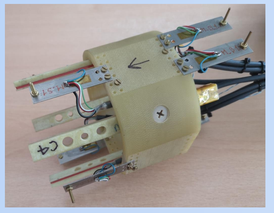
The beam screen assembly has been instrumented with:

- 20 bi-axial strain gauges along 3 sections;
- 3 custom-made probes equipped with pick-up coils;
- 4 optical fibres equipped with 3 biaxial measuring points each.

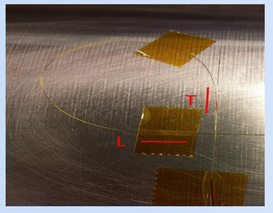
Compensator strain gages have been installed to account for spurious thermal and magnetic effects.



Strain gauges to measure the deformations of the beam screen

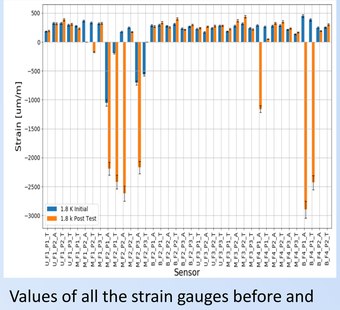


Probe to measure the expansion, the tilt and the magnetic field

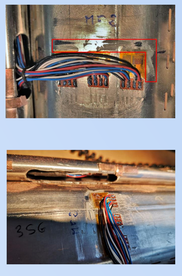


Optical fibres to measure the strain on the cold bore

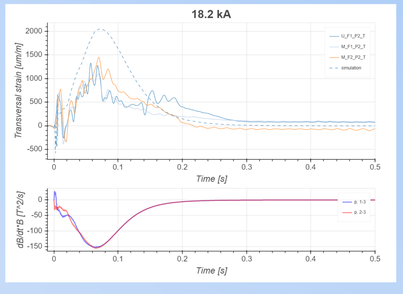
Results



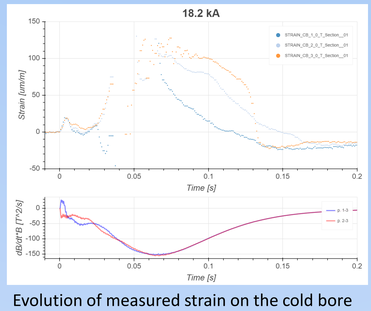
Values of all the strain gauges before and after the test campaign at 1.8 K



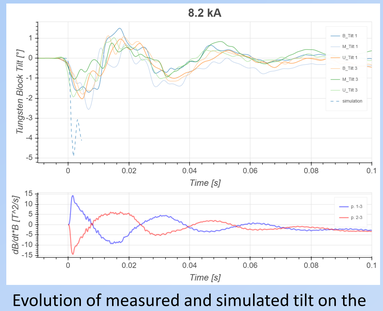
Damaged strain gauges giving the faulty results



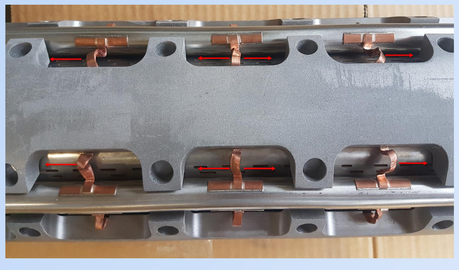
Evolution of measured and simulated strain on the BS at 18.2 kA along with the magnetic measurement



Evolution of measured strain on the cold bore at 18.2 kA along with the magnetic measurement



Evolution of measured and simulated tilt on the BS at 8.2 kA along with the magnetic measurement



Thermal links after the test campaign. The distribution of the induced forces is represented by red arrows

Conclusions

The mechanical integrity of the Q1 beam screen has been demonstrated. The behaviour of the beam screen remains elastic after 54 quenches up to 18.2 kA of current (ultimate current 17.8 kA). The beam screen components have been visually inspected after the quench test and no damage nor unexpected deformation has been observed.