Optimizing the use of pressurized bladders for the assembly of superconducting magnets: the HL-LHC MQXF magnet case

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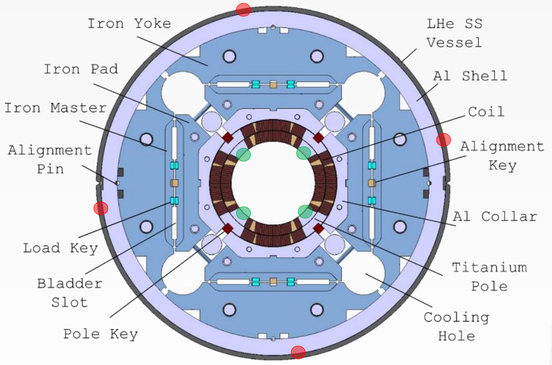
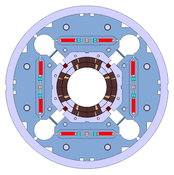
*The **assembly** of **Nb_3Sn** accelerator **magnets** requires the careful **control** of the mechanical **loads** experienced by the superconducting **coils**, in order to **decrease** the **risk** for conductor **degradation**. The present work reports on the **results** of an **experimental** and numerical **modelling campaign focused** on the **optimization** of the "**bladders and keys**" assembly **process** in the novel **MQXF quadrupoles**.*

I – MQXF Magnet

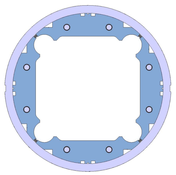
Low-β quadrupole magnet for the HL-LHC upgrade



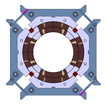
Magnet with original bladders

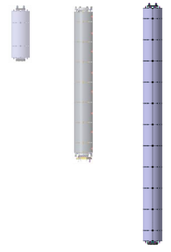


Yoke-shell



Coil-pack





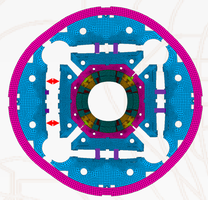
First accelerator magnet to be installed in a particle accelerator using:

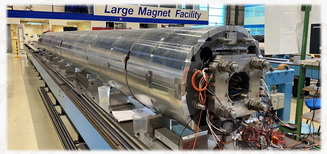
- Nb_3Sn technology
- Shell-based support structure

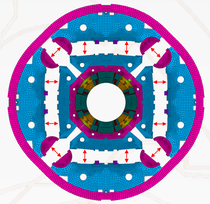
Three magnet versions built up to date:

- MQXFS – Magn. length = 1.2 m
- MQXFA (US-AUP) – Magn. length = 4.2 m
- MQXFB (CERN) – Magn. length = 7.2 m

II – Investigation on bladder and key assembly: novel strategy







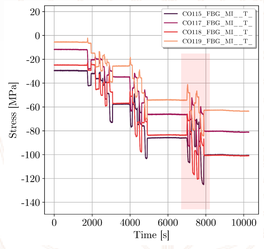
Quadrant-by-quadrant procedure:

- Used in MQXF short models, MQXFA and in the three first MQXFB prototypes.
- During bladder pressurization, stress overshoot in the coils located opposite to the active bladders.

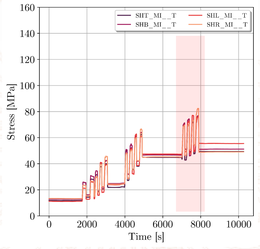
Optimized symmetric procedure:

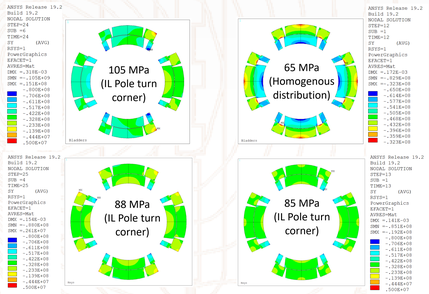
- Incorporates new bladders in the cooling hole channels (acting on the iron yoke).
- Removes the stress overshoot. Coils unload when bladders are pressurized.

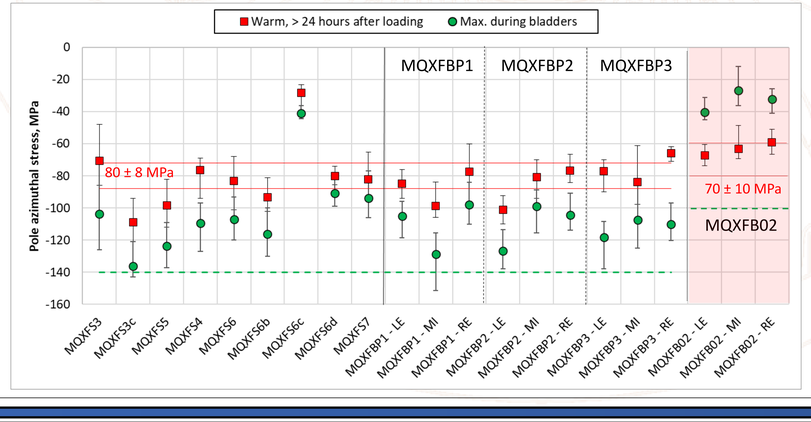
Coil (MQXFBP3):



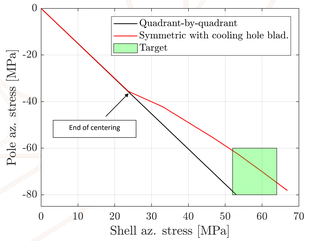
Shell (MQXFBP3):







Pre-load transfer function:

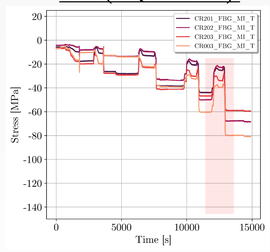


III – Results

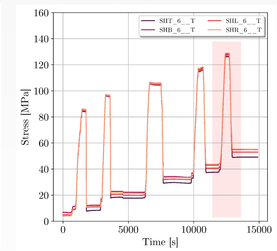
New procedure successfully implemented in:

- Full-length mechanical assembly test (MQXFBMT3).
- Short model magnet MQXFS7.
- And finally, in a real MQXFB magnet: MQXFB02

Coil (MQXFBMT3):

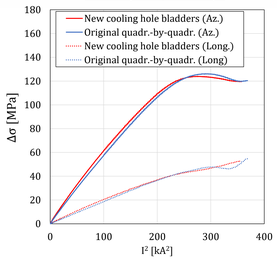


Shell (MQXFBMT3):

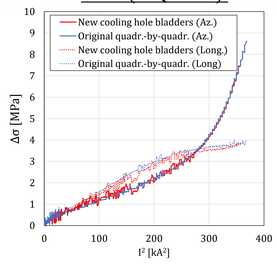


No detrimental effect on magnet performance. Same mechanical state at cold than previous method.

Coil (MQXFS7):



Shell (MQXFS7):



IV – Conclusions

- A successful optimization of the B&K assembly procedure in MQXF magnets has been presented.
- The proposed solution removes the coil peak loads during bladder pressurization. New bladders added in the yoke.
- The optimized method allows for more stringent criteria in coil peak stress limits during assembly. For MQXF, now set to 100 MPa.
- Successfully tested and applied to full length magnets.