Production of a MQXFB practice coil without ceramic binder on the OL

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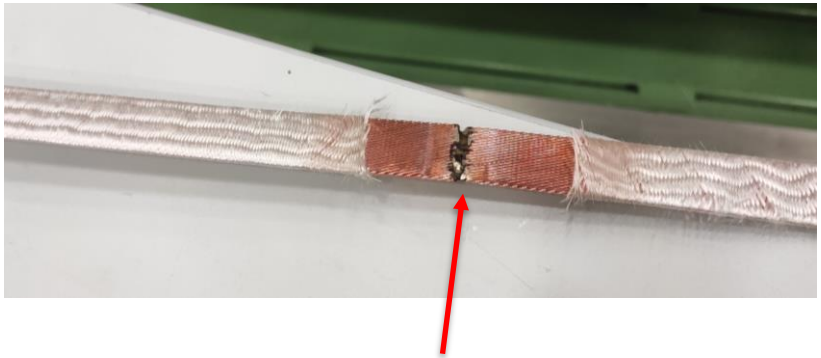
11 November 2020

Introduction on MQXFB coil CR120

- During the outer layer winding of MQXFB coil CR120, there was a critical non-conformity (EDMS 2421749).
- The coil was degraded to practice coil and, once the winding completed, it was decided to:
  - Not apply ceramic binder on the outer layer;
  - Perform anyway a dry curing (entire thermal cycle).



Cable needed to be cut and welded then a repair of the insulation was performed (binder was applied to keep the insulation in place)

Motivation

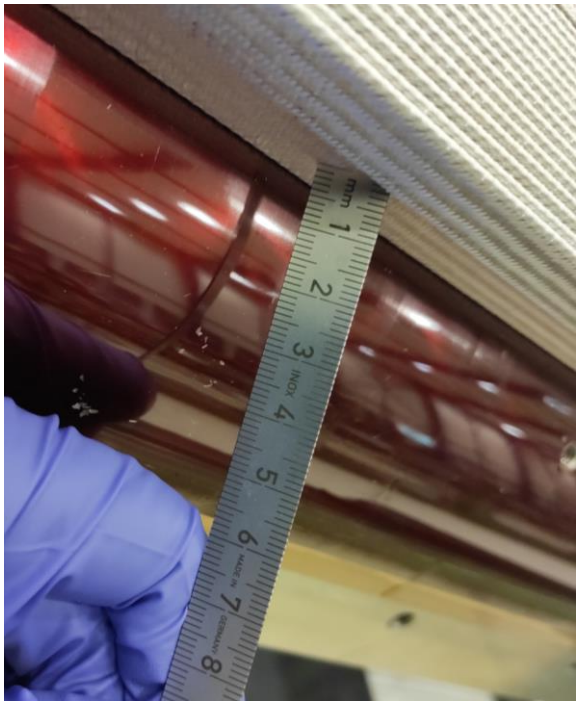
- Feasibility to produce a MQXFB coil without ceramic binder (in that case only on the OL).
- Impact of the ceramic binder on the coil fabrication process:
  - Handling of the coil;
  - Position of the turns;
  - Brittleness of the fiberglass insulation after reaction cycle;
  - Resin adhesion to “fresh” fiberglass;
  - Insulation resistance (QH to coil, coil to pole).

Motivation

- As a remainder, here below the quantity of ceramic binder applied for:
  - MQXFB:
    - 30 g/m per side on the straight part, for IL and OL, missing the first 4 turns around the poles;
    - 6.5 g on each end.
  - MQXFS:
    - 47 g/m per side on the straight part for IL and OL;
    - 26 g on each end.
  - MQXFA:
    - FNAL:
      - 276 g in total for the IL → 35 g/m per side on the straight part;
      - 324 g in total for the OL → 41 g/m per side on the straight part;
      - No binder on the ends since it is already applied and cured during winding.
    - BNL:
      - 250 g in total for the IL → 31 g/m per side on the straight part;
      - 330 g in total for the OL → 40 g/m per side on the straight part;
      - A light coat of binder is applied on the ends.

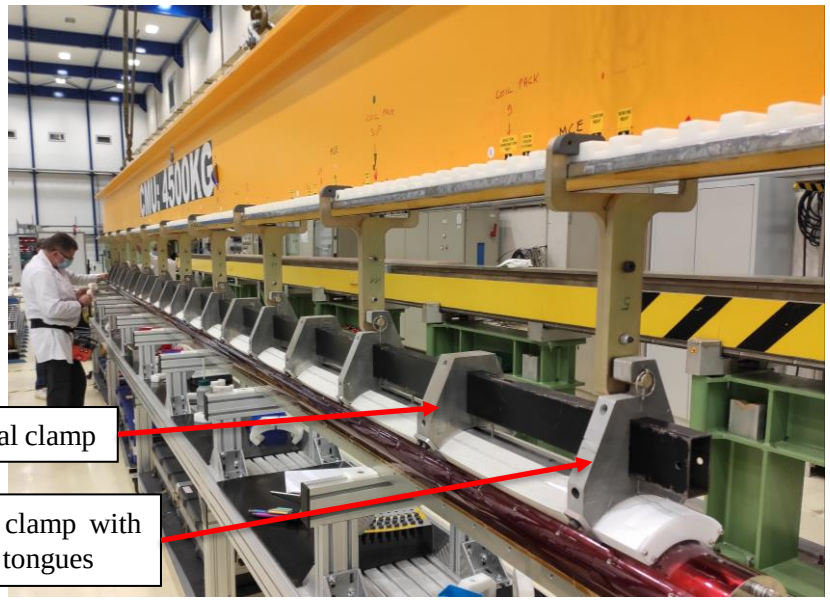
Behaviour of the coil after curing without binder on the OL

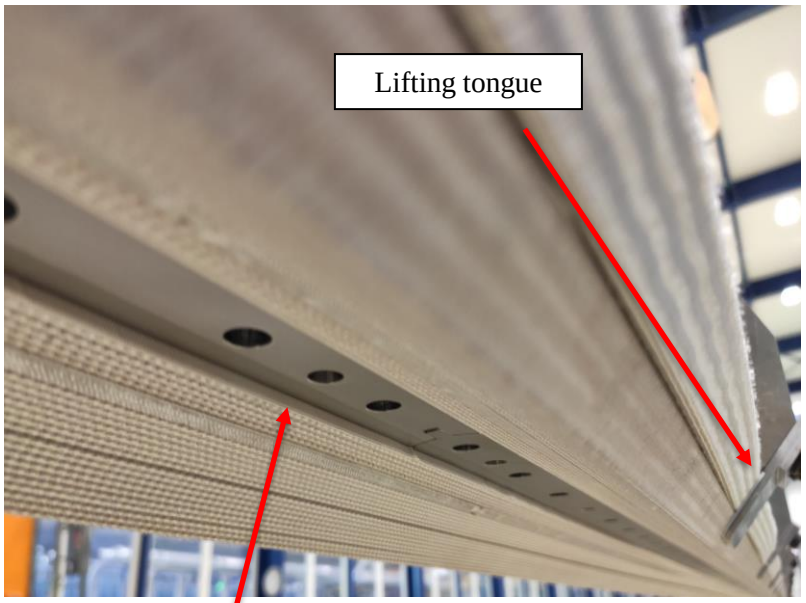
- Once the curing finished, starting from CS the side bars and the curing shims were removed showing a difference in the stiffness of the coil:
  - The IL was more rigid than the OL
  - A gap of about 2mm was measured between the cable on the OL and the IL along the whole length of the coil



Handling of the coil

- Lifting beam with additional and modified clamps was used.
- The turns in the IL close to the poles were below by almost 4mm with respect to the poles along the length:
  - Probably due to a not uniform pression given by the lifting tongue during the screwing.





Modifications at the level of the lifting tooling

- As a remainder, here below the modifications implemented to the lifting tongues:
  - The number of pieces was increased from 10 to 18;
  - The width of the additional pieces was increased from 30mm to 50mm;
  - The thickness of the lifting tongues was decreased from 8mm to 4mm (1mm of PTFE in contact with the coil) and the material was changed to high strength steel (15 NiCr 13);
  - The screwing system was changed passing from M6 rods + wing nuts to threaded hole in the lifting pieces + M8 screws.

Preparation for reaction heat treatment

- Once the coil in the reaction cavity, two differences were noticed:
  - The coil was bigger than the cavity along the whole length, indicating that the dry curing cycle was not efficient enough to guarantee the compression of the OL ;
  - A kind of spring effect was experienced trying to put back in place the turns.

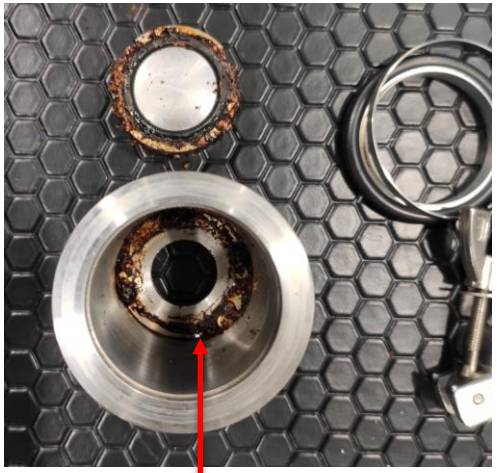
A gap of 5mm was measured between the reaction blocks and the base plate indicating an over dimension of the coil due to its elastic behaviour (normally a gap of 2mm is measured)

- Due to the overgap, additional steps were added to the closing procedure to gently guide the coil in the reaction cavity.

Observations after reaction cycle

- Recalling the differences between pratice coil CR120 and normal MQXFB production conditions:
  - Increased Ar flow in the fixture from 250l/h to 500l/h at the inlet;
  - No ceramic binder on the outer layer.
  - Additional RRR samples placed along the coil in the pole groove.
- The main observations, once the cycle finished, are:
  1. The cleaner condition of the overpressure valve at the outlet of the retort.

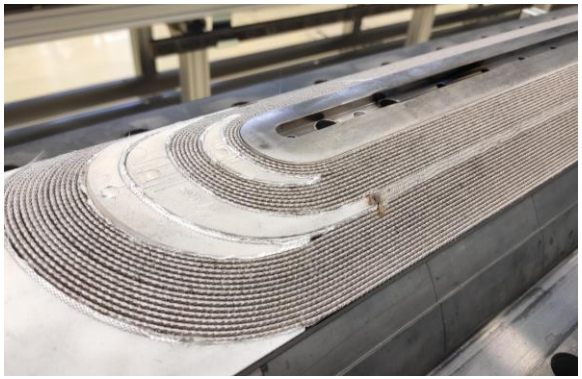
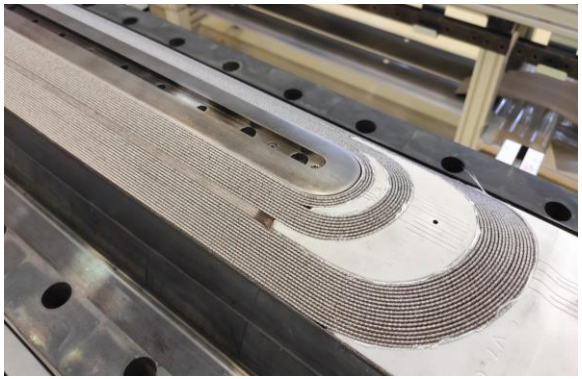
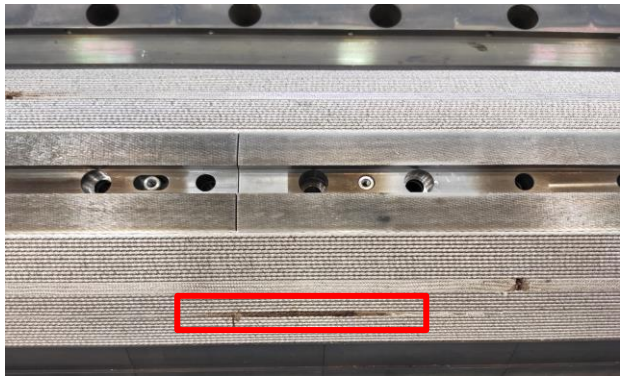
Dirtness normally observed in the overpressure valve



Dirtness in the overpressure valve for practice coil CR120

Observations after reaction cycle

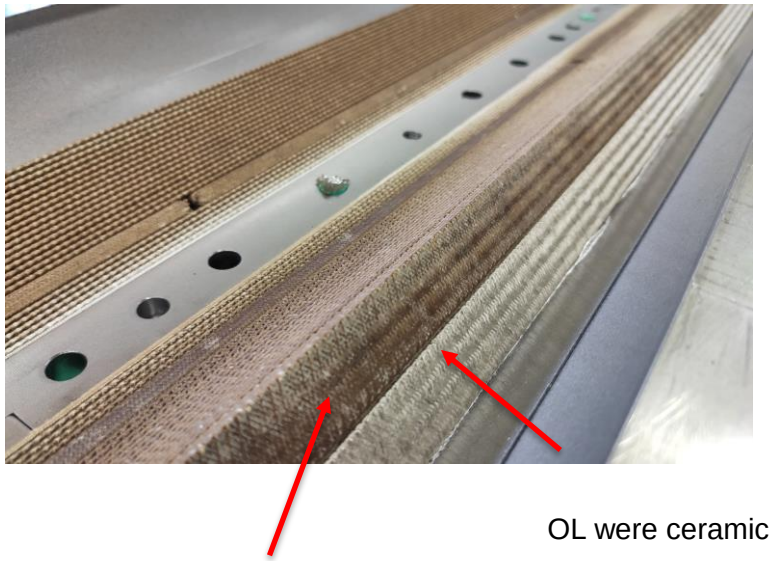
2. The color of the fiberglass insulation once the OL exposed: silverish aspect of the fiberglass with darker regions where binder was applied (repair area and wedges extremities);

3. In terms of quality, the robustness of the fiberglass insulation was comparable to a non-reacted fiberglass and tested in different ways:
    - Trying to manually scratch it away;
    - Light vacuuming the surface of the coil from mica and fiberglass residuals staying closer than usual.
4. The position of the turns and the geometry were as usually observed with binder cured MQXFB coils.

Observations after reaction cycle

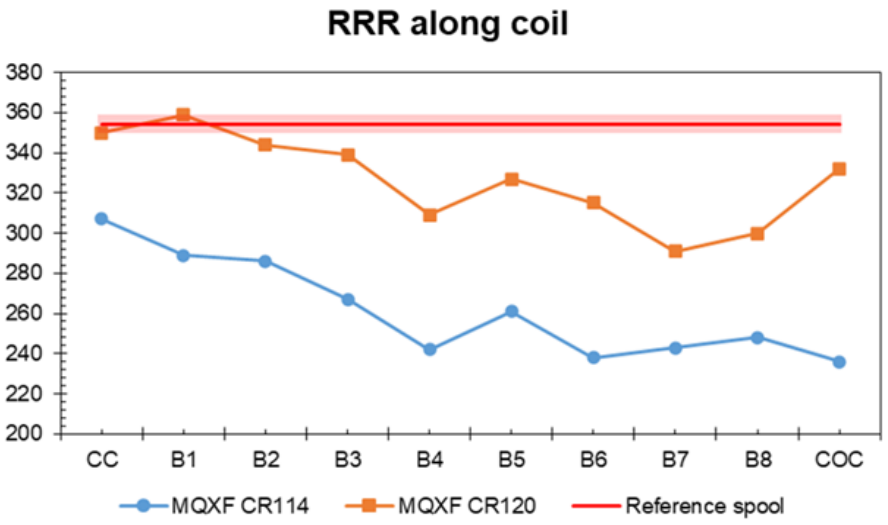
5. With the IL exposed, a difference in the colour between the two layers could be easily detected (all the pictures can be found on EDMS 2431174) .
6. The robustness observed on the OL does not extend to the midplane (same fragile behaviour observed in the two layers).

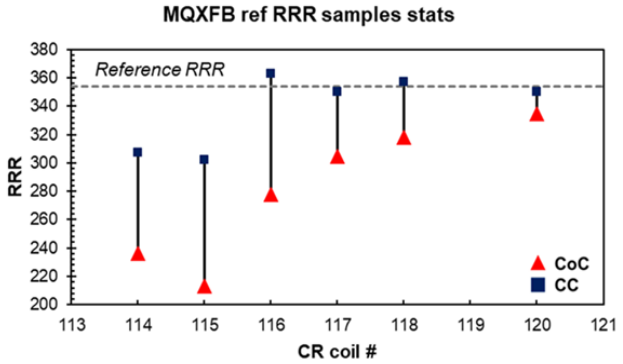


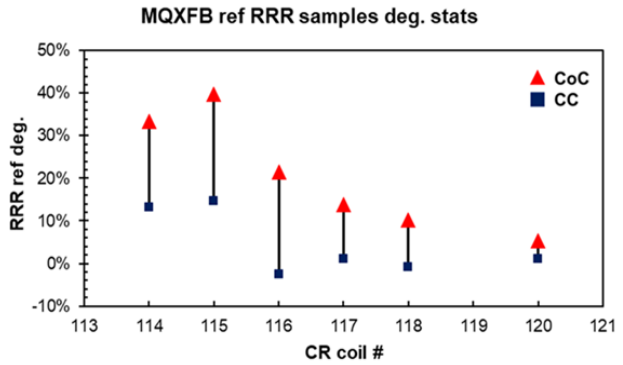
Observations after reaction cycle

Analysis of samples placed in the VAMAS box and along the coil shows interesting results:

- Increased RRR along the coil with respect to CR114 (last coil where additional samples were placed) that accounts for all the improvements implemented in terms of mould sealing.
- Combined effect of increased Ar flow and no ceramic binder on OL has reduced ref. degradation to 5% in NCS.







Credit to Dario Baffari

Conclusions

- MQXFB practice coil CR120 was cured without ceramic binder on the OL and handled with an improved lifting beam.
  - Further improvements have to be taken to better load the inner layer of the coil, in case of coils partially without binder.
- The coil is now prepared for impregnation.
- Cross-sections might be cut to check the correct placement of the turns.
- Decouple the effect of the increased Ar flow from the missed ceramic binder on the OL for the next coil (CR121).
  - Additional RRR samples along the coil in the pole groove will be placed.
- Using the current tooling, it may be risky to produce a MQXFB coil completely without ceramic binder because of the risk the turns in the IL have to slide down with respect to the poles.
  - Re-designing the tooling in order to reduce the handling of the coil and to guarantee always a rigid support below the IL.

Thank you!