HiLumi
HL-LHC PROJECT

MQXFB strategy and plan

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CERN

29 April 2022

THE THREE BULLET STRATEGY

- In June 2021 we elaborated the «three bullet strategy» to cope with performance limitations observed in MQXFBP1 and MQXFBP2
  - MQXFBP3 (previously called MQXFB01): test of cold mass with revised welding procedures and including fixed point
  - MQXFB02: test of cold mass with revised magnet assembly procedures – to be seen as a pre-series magnet
  - MQXFB03: test of cold mass with coils with revised procedures

- Now we add an additional test: MQXFBP01b to rapidly test a coil made with revised procedures, together with 3 coils manufactured before the production stop
  - All tests will have the possibility of enhanced trimmed powering, i.e. to see the performance of the four coils, and not only of the limiting one (see talk by S. Russenschuck)

THE NEW ELEMENTS SINCE LAST MEETING ON NOVEMBER 2021

- Since November 2021, significant advancements in different areas
  - Broken filaments were observed at the quench start location (in the central part as indicated by quench antenna, and in the inner pole turn as indicated by the voltage taps), consistent with the quench phenomenology (S. Sgobba talk)
  - Trimmed powering technique was proposed and demonstrated: first on a short model and then on a prototype: this allows see the limitations in each coil, within a 1-2 kA range (S. Russenschuck talk)
  - MQXFBP2 shows the same limitations at higher cureent levels in two more coils, and no quenches in coil heads up to 17 kA (A. Milanese talk)
  - Revised procedure of assembly allowing to reduce peak stress during assembly by ~40 MPa (S. Izquierdo Bermudez talk)
  - Welding and fixed point strategy defined and supported by international review (H. Prin talk)

OTHER RELEVANT ELEMENTS: PERFORMANCE VERSUS LOAD

- Ongoing program on characterization of cable performance under transverse load, done for 11 T and available for MQXF in June 2022 (see A. Ballarino talk)
  - Limits on appearance of microcracks ~150 MPa
  - Limits on critical current degradation towards ~180 MPa
  - (numbers seen for 11 T cable, to be updated with MQXF cable results)
- With the new assembly procedure (see S. Izquierdo Bermudez talk) we can be well below the microcrack limit during assembly
- MQXF design: 105 MPa accumulated stress in the midplane at nominal (7 TeV), 120 MPa at ultimate (7.5 TeV)
  - Short models performance reached 19.3 kA, corresponding to ~150 MPa accumulated stress in the midplane
  - Endurance tests on short model were not done not above ultimate current
- Feedback
  - Hard limit on the powering of magnets to be installed, including endurance tests: not above ultimate
  - Possibility of further program of endurance test on one short model, well above ultimate current

OUR UNDERSTANDING OF THE PRESENT SITUATION

- Performance limitation (repeatable quench performance at a level below nominal) and performance degradation (progressive degradation of quench performance as a function of electromagnetic and thermal cycling) are two recurrent issues with Nb_3Sn coils and magnets
- Performance limitation has been observed on short and full-length 11 T dipole magnet models and on full-length MQXFB quadrupole magnets; the root cause is likely to be excessive transverse stresses or local bending applied by external loading during coil manufacture and handling or magnet/cold mass assembly
- Performance degradation has been observed on ITER CICCs and on full-length 11 T dipole magnets; the root cause is likely to be improper mechanical support of Nb_3Sn conductors enabling local strand bending and/or displacement under the effects of Lorentz forces and thermal shrinkage differentials, which cumulate and induce fatigue effects
- Both root causes point to issues with detailed engineering design and manufacturing processes which prevent achievement in a reproducible manner of Nb_3Sn conductor potentials; it is an engineering problem, not a technology nor a superconductor performance issue

TEST PLAN FOR SOLVING PERFORMANCE LIMITATIONS

- Test sequence and plan for the temporary cold masses
  - Cold masses without nested corrector, reducing manufacturing time by 2 months, and allowing trimmed powering to bypass limitations and fully characterize the performance of the four coils (See talk by S. Russenschuck)
  - MQXFBP3: test at the end of July 2022
    - Cold mass manufacturing with the revised welding procedure and the fixed point is ongoing (after the succesful review held in April)
    - Using coils done in 2019-2020, assembled and loaded in 2021 (old procedure)
  - MQXFB02: magnet assembly starting in May, loading in June, test in November 2022
    - Magnet implementing the revised procedure for magnet loading (after technical meeting to assess preload targets in May)
    - Coils were manufactured in 2020-2021, old procedures
  - MQXFBP1b: additional magnet to rapidly test a coil manufactured in 2022, test in March 2023
    - The other three coils (manufactured before 2022)
    - Magnet assembly starting in September
  - MQXFB03: first magnet with coils manufactured in 2022
    - Magnet assembly starting in March 2023, after test of P1b, and test in July 2023

PLAN FOR STRING

- LQXFBP2 in final configuration: test in February-March 2023
  - To be welded in September, after feedback from MQXFBP3 welding and test
- LQXFBP3 in final configuration: test in April-May 2023
- The six cryomagnets required for string (Q1, 2 Q2, Q3, CP and D1) will be available for string installation between June and October 2023
  - In case of issues of MQXFBP3 performance, MQXFB02 will be the backup for the string, test in final configuration in August 2023, string-ready in November 2023
- Including the test at CERN of the second Q1/Q3 from AUP (not in the baseline), and contingency of using LQXFB02 instead of LQXFBP3, magnets for string installation available between June 2023 and December 2023

APPENDIX

- MQXFBP3:
  - 4 existing coils with dromedary hump
  - Existing magnet assembly with bladdering overshoot
  - New shell welding with reduced mechanical coupling and fixed point
- MQXFB02
  - 4 existing coils with dromedary hump
  - New magnet assembly without bladdering overshoot
  - New shell welding with reduced mechanical coupling and fixed point
- MQXFBP1b
  - 1 new coil with new procedure (to reduce dromedary hump)
  - 3 existing coils with dromedary hump
  - New magnet assembly without bladdering overshoot
  - New shell welding with reduced mechanical coupling and fixed point
- MQXFB03
  - 4 new coils with new procedure (to reduce dromedary hump)
  - New magnet assembly without bladdering overshoot
  - New shell welding with reduced mechanical coupling and fixed point