US HL-LHC Accelerator Upgrade Project

Report of the MQXFA16 Structure & Shim Review

August 10th 2023

– Peter Wanderer, chairperson (BNL)
– Mike Anerella, (BNL)
– Rodger Bossert, (FNAL)

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1. Goal and scope

The HL-LHC AUP project is starting the assembly of MQXFA16 magnet. This is the 9th series magnet of the MQXFA low-beta quadrupoles to be used in Q1 and Q3 for the High Luminosity LHC. If MQXFA16 meets MQXFA requirements [1] it will be used in a Q1/Q3 cryo-assembly to be installed in the HL-LHC.

AUP is planning to install MQXFA16 and MQXFA17 in a cold mass without previous vertical test.

MQXFA16 coils were reviewed on July 11, 2023 [2].

MQXFA16 is going to use the MQXFA13 structure if it passes all QC tests during MQXFA13 disassembly.

MQXFA Series magnet specifications are presented in [3]. Discrepancy or Non-Conformity Reports are generated whenever a component does not meet specifications [4]. The MQXFA16 structure was reviewed and approved during the MQXFA13 Structure and Shims Review [5]. The goal of this review is to evaluate the MQXFA16 shim plan and that MQXFA13 structure can be used for MQXFA16.

Reviewers should also assess that the discrepancies and non-conformities of MQXFA13 structure, found during MQXFA13 disassembly, have been adequately processed.

Committee

Peter Wanderer, chairperson (BNL)

Mike Anerella, (BNL)

Rodger Bossert, (FNAL)

Date and Time

August 10, 2023.Start time is 7:00/9:00/10:00/16:00 (LBNL/FNAL/BNL/CERN)

Location/Connection

Video-link by Zoom, info by email.

Link to agenda with talks and other documents

https://indico.fnal.gov/event/60732/

2. Review Charges responses

The committee is requested to answer the following questions:

1. Have all recommendations from previous reviews [6] been adequately addressed?

Yes.

2. Have discrepancies and non-conformities been adequately documented and processed?

Yes. Discrepancies and non-conformities from the MQXFA13 structure assembly and disassembly were included.

3. Is the MQXFA13 structure OK for use in MQXFA16?

Yes.

4. Are the proposed shims adequate for allowing MQXFA16 to meet MQXFA requirements [1]?

Yes. *Shims with thicknesses calculated for the coil straight section should be installed in the full length of the coils.* In the presentation by P. Ferracin [6], a change in the procedure for calculating shims was proposed. The change was based on an analysis of the MQXFA13 training and assembly data and a finite element model of the wedge/end-spacer transition region. The shim calculation made use of the difference between the shims for successful magnets (MQXFA14b and MQXFA05) and the slow training of MQXFA13. It took account of the difference in the sizes of the upper and lower halves of MQXFA16.

5. Do you have any other comment or recommendation to assure MQXFA16 is going to meet requirements?

See below.

Comments

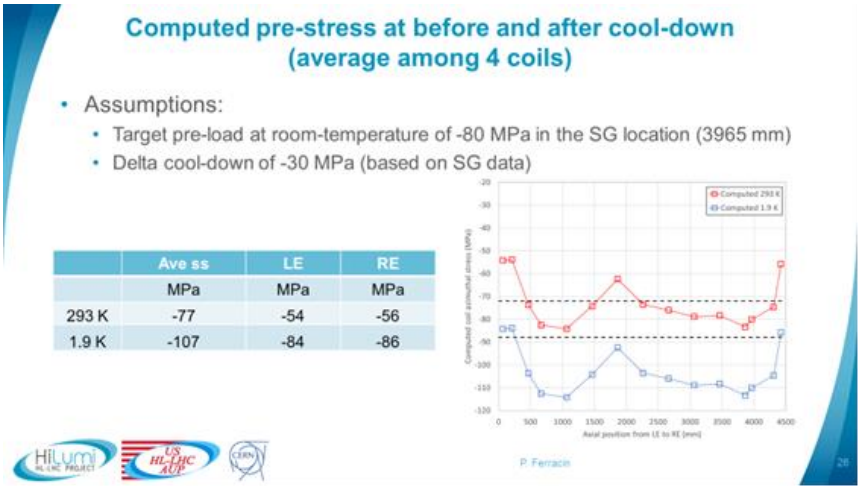
The committee felt that development of a procedure for installing shims in the coil ends that are not the same thickness as the shims in the coil straight section will delay the schedule for magnet MQXFA16.

The target prestress of 80MPa +/- 8MPa is for the entire length of the magnet (see first figure below). The purpose of taking azimuthal size measurements at the strain gauge location is to be able to calculate minimum and maximum azimuthal prestress at the remaining coil measurement locations. This is incorrectly stated as being specific to the strain gauge location (see second figure below). Based on the data provided (see third figure below) the minimum prestress at room temperature is 54MPa at lead end and 56MPa at non-lead end, not 77MPa as previously reported, significantly lower than the target, and unloading of the coils at the poles is to be expected at lower current in these

areas. Increasing preload in all coil regions to the target value could possibly be accomplished without impacting the maximum load by employing CERN-style yoke bladders during assembly.

- Azimuthal pre-load
  - Target coil pre-stress at cold of 100 MPa requires:
    - **~80 ± 8 MPa** at R.T. after 24 hours

- Assumptions:
  - Target pre-load at room-temperature of -80 MPa in the SG location (3965 mm)
  - Delta cool-down of -30 MPa (based on SG data)



3. Recommendations

Consider checking correlations of training quench locations of this magnet (and perhaps earlier magnets) with measured minimum azimuthal coil sizes to determine if adjusting shim thicknesses locally would be beneficial.

4. References

1) *MQXFA Functional Requirements Specification,* US-HiLumi-doc-36.
2) *MQXFA16 Coils Acceptance Review*, US-HiLumi-doc-4900.
3) *MQXFA Series Magnet Production Specification*, US-HiLumi-doc-4009.
4) *Handling of Discrepancies and Nonconformances*, US-HiLumi-doc-2484.
5) MQXFA13 Structure and Shims Review, US-HiLumi-doc-4747.
6) *MQXFA15 Structure and Shims Review*, US-HiLumi-doc-4852.

7) P. Ferracin et al., “Analysis of A13 and loading shim proposal for A16,” presentation, August 10, 2023.