Magnets Working Group Meeting Notes

Magnet Working Group

27 April 2023

News

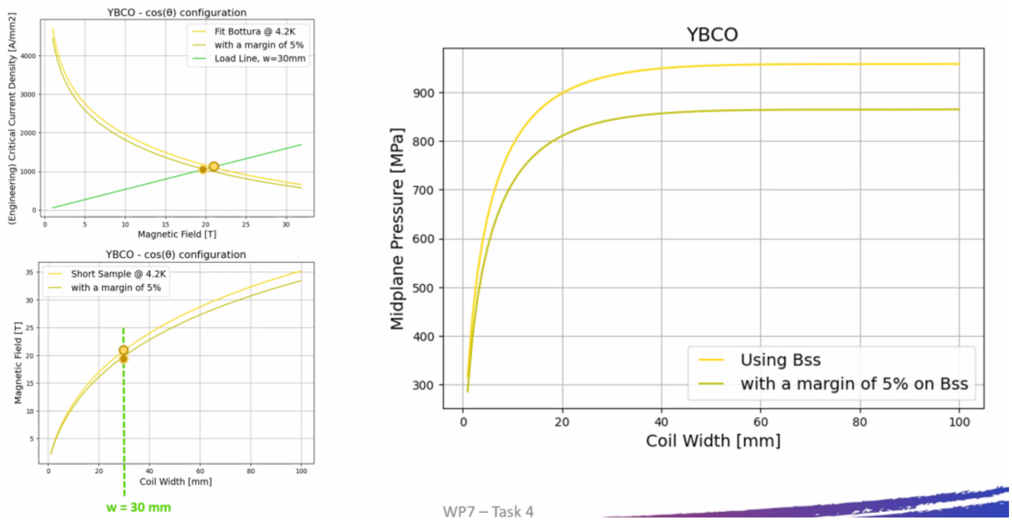
- **Annual Meeting in Orsay June 19-22** **https://indico.cern.ch/event/1250075/registrations/91716/**
    - **See the Mandate Internal Review**
- **Muon Collider Synergies Workshop June 22-23 in Orsay**
    - **https://indico.cern.ch/event/1260921/timetable/#20230622.detailed**

Presentations

Accelerator Magnets Performance Limits - Margin and Mechanics, Daniel Novelli, Barbara Caiffi et al. Task 4

Some key notes

- No-Iron hypothesis
- Python code with analytic formulas for dipole and quadrupole in the cos-theta approximation
- More complicated configurations (sector magnets with Iron yoke) can then be studied
- Setup:
    - Bore radius:
    - Temperatures:
    - D
- Dipole performances of NbTi
    - Fits the data from LHC cable
- Dipole Performances of Nb3Sn
    - Fits data from the FCC target performance
- Dipole performances of YBCO (Cosθ configuration)
    - **Fits data** from FujiKura FESC AP tape, **Fixed aperture** = 75 mm, **T** = 4.2 K, **Filling factor** = 0.02



- Dipole – temperature studies (see plots on slide 8):
    - 1.9 K : NbTi, Nb3Sn
    - 4.2 K : NbTi, Nb3Sn, YBCO
    - 10 K : YBCO

- 20 K: YBCO
- Studying the quadrupole – Complexity – the peak field inside a quadrupole is not equal to the field at the inner aperture!
- Quadrupole performance of NbTi
  - Fits data from LHC cable, T = 4.2 K, Fixed aperture = 75 mm, $R_{ref} = \frac{2}{3}$ *radius of aperture, Filling factor = 0.3, Cosθ configuration
- Quadrupole performance of Nb3Sn
  - Fits data from FCC target performance, T = 4.2 K, Fixed aperture = 75 mm, $R_{ref} = \frac{2}{3}$ *radius of aperture, Filling factor = 0.3, Cosθ configuration
- Quadrupole performance of YBCO **
  - Fits data from Fujikura FESC AP tape, T = 4.2 K, Fixed aperture = 75 mm, $R_{ref} = \frac{2}{3}$ *radius of aperture, Filling factor = 0.02, Cosθ configuration
- Quadrupole – Gradient study
  - 4 different temperatures: 1.9 K NbTi, Nb3Sn; 4.2 K NbTi, Nb3Sn, YBCO; 10 K YBCO; 20 K YBCO. Fixed Aperture: 75 mm.
- Discussion on the Margin -> see slide 19

Some questions / comments

- Define the margin better – which kind of margin, comparing margins (the point of this method is to identify how to proceed)
- Strange behavior – Midplane pressure on RBCO flattens out versus Coil Width
- Bernardo – HTS , did you also use angular dependence of critical current dependence? …. Use lower critical current for a certain field on the trap.
- Christian – why did you make difference b/w aperture radius and reference radius for quadrupoles? Answer: for quadrupoles, we must fix a radius to compute the field from analytic formula, reference radius is just a place where you compute the field and load line
- Christian – sector magnets: you go from straight magnets to bent magnets (cosθ Approximation is an approximation.
- Christian – everything so far was done with same aperture 75 mm, timeline for studies of other apertures? … no clear answer
- Fulvio – what beam pipe correspondes to 75 mm magnet aperture? - ~25 mm from cryogenic+vacuum group
  - Christian - the radial build shown is probably very close to what is needed for the arc cells. Larger apertures will be needed close to the IP.
  - Fulvio – for resistive magnets we are considering a beam pipe radius of only ~ 15 mm…..
- J Scott berg – Simple curves with finite number of technology options, with some things like coil thickness factored out -> so a simple view without too much details for the designers
- Alfredo P – what assumption have you made about the strain in the conductor – the scaling law includes a value of strain? Ans. : we did not include these details, just took the material curve with a 20% margin, this study is purely electromagnetic and analytic. The pressures we showed are not stress but the azimuthal summation of the Lorentz force. This is not a mechanical analysis.
- Luca Bottura – we can't tolerate stress above 150 to 200 MPa, the coil width for a certain aperture can't become to big otherwise you can't build it. Looking at the plot of bore

diameter vs bore field _> bore diameter of 150 mm… for 100MPa means bore field only around 5 T.

Analytical estimation of LTS accelerator magnet limits from quench protection – Tiina Salmi et al.

Some key notes

- Idea: have analytical equations to start from dipole field and obtain coil current density,
- Magnet current versus time: hot spot, detection, time for detection system to activate protection, quench and decay of current
    - Coil absorbs stored energy
- Fix the max temperature allowed hotspot (350 K), we can compute the allowed ‘quench load’ Γ_{Tmax}
    - From a series of integral equations (see slide), we can solve the total current density
- Quench protection can be the limiting factor – important to consider this from beginning
- For a coil with width < 30 mm, strong increase in current density and stored energy density
- Next steps

Some questions / comments

- Luca Bottura – cost is 500k for half a meter of NbSn

Update on the Benchmark on MUC magnetic field calculation – Pietro Testoni

Some key notes

- Benchmark exercise to validate 3 different numerical codes for the design of the MUC
    - Compares 3 components of the magnetic field along four different paths
- Three different numerical codes used to run simulations: ANSYS, current-loop approximation, Daniele C++ code
    - Current loop approximation is run with 2 different settings (see slide)
        - Singularity at source point overcome by skipping contribution of source point
    - Daniele C++ code is run with:
        - 600 layers per magnet
        - Singularity is overcome by zero contribution from radial element at that point
- Conclusions
    - The 3 codes provide results in good agreement
    - The current assumption of the tapering field follows the inverse cubic field from past MAP studies. Deviation from this function are fine as long as the magnetic field decrease is adiabatic.

Some questions / comments

- Luca Bottura - Errors in 10^5 in H…. For Daniele, neglect the layer (or loop for loop model) that has the infinity at this distance. Write down the recipe completely.
- Jose – I use the current loop approximation outside the coil or at the boundary. For inside the coil use different approximation.

AOB

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