20 T DIPOLE MAGNET BASED ON HYBRID HTS/LTS COS-THETA COILS WITH STRESS MANAGEMENT*

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Introduction

20 T dipole magnets are being considered for the next generation of particle accelerators. The 20 T field level is above the practical limit of Nb_3Sn accelerator magnets and therefore it requires using SC materials such as High Temperature Superconductors (HTS). The high cost of HTS and the more complicated technology of HTS magnets make a hybrid approach attractive to minimize the volume of HTS coil. HTS is used in the high field part of the coil and Nb_3Sn is used in the outer, lower-field coil regions.

This paper presents a design concept of a dipole magnet with 50 mm aperture and 20 T nominal field with 13% margin based on the cos-theta (CT) coil design and a cold iron yoke. Due to the high stresses and strains in the coil at high fields, a Stress Management (SM) concept combined with the CT coil geometry is used.

Magnet design and parameters

Table 1. Strand and cable parameters

Parameter	Cable 1	Cable 2	Cable 3
Superconductor	Bi2212	Nb_3Sn	Nb_3Sn
Strand diameter, mm	1.0	1.0	0.7
Cu/nonCu ratio	3.0	1.1	1.1
$J_c(15T;1.9K)$, A/mm^2	3750	2000	2000
Number of strands	32	40	40
Cable width, mm	16.5	20.1	15.0
Cable small edge, mm	1.85	1.70	1.22
Cable large edge, mm	1.95	1.90	1.38
Cable packing factor	0.83	0.90	0.81

Table 2. Coil parameters

Parameter	Value
Number of layers	6
Number of blocks	6 HTS+12 LTS
Number of turns/coil, L1-2/L3-4/L5-6	31/52/63
Coil inner/outer diameter, mm	50/310
Bi2212 coil area/quadrant, mm^2	972
Nb_3Sn coil area/quadrant, mm^2	3110

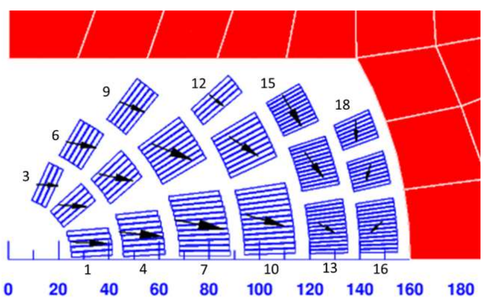

Figure 1: Cross-section of one quadrant of the 20 T dipole with cold yoke. Coil blocks are numbered and the Lorentz force vectors in the coil blocks are shown by the arrows.

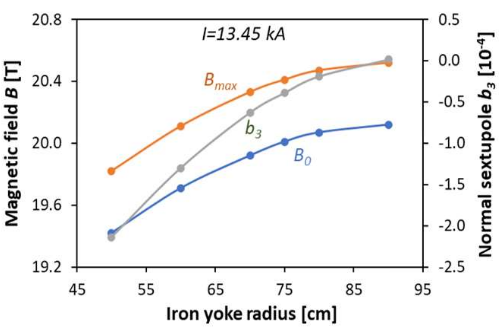

Figure 2: Effect of the iron yoke OD on B_{max}, B_0 and b_3 at a coil current of 13.45 kA.

Table 3. Geometrical field harmonics at R_{ref}=17 mm

n	3	5	7	9
b_n, 10^{-4}	-0.24	5.83	7.54	-0.98

Table 4. Magnet parameters

Parameter	Value
Coil nominal current I_{nom}, kA	13.45
Coil nominal field B_{nom}, T	20.0
Coil to aperture field ratio B_{max}/B_o	1.02
Coil inductance @I_{nom}, mH/m	52
Stored energy @I_{nom}, MJ/m	4.7
Lorentz forces F_x/F_y @I_{nom}, MN/m	14.9/-7.4

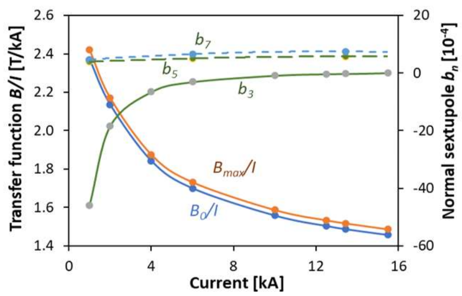

Figure 4: B_{max}/I, B_0/I and b_3, b_5 and b_7 vs. coil current.

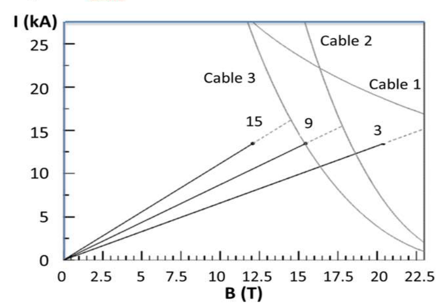

Figure 6: $I_c(B)$ curves at 1.9 K of the three cables used in the dipole, and load lines of the key coil blocks.

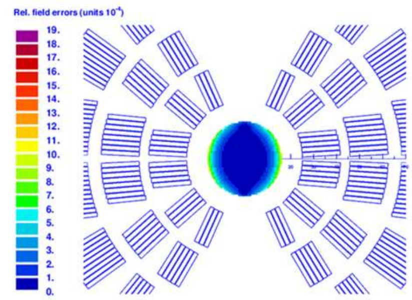

Figure 3: Field quality in the aperture within the 16 mm radius circle at a bore field of 20 T.

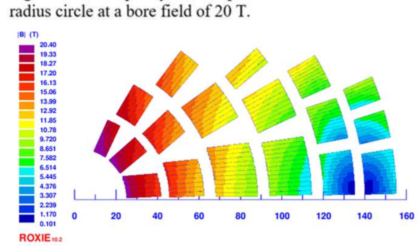

Figure 5: Magnetic field variation in the coil at B_0=20 T.

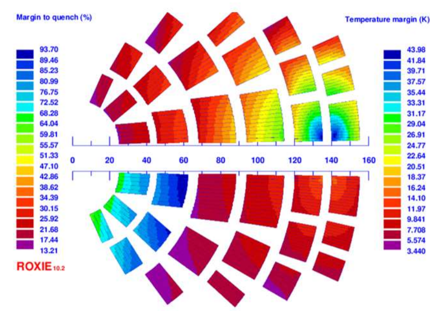

Figure 7: Margin to quench (top) and temperature margin (bottom) of the coil at the nominal field of 20 T and operation temperature 1.9 K.

Conclusion

A conceptual design of a 20 T hybrid dipole demonstrator based on Bi2212 and Nb_3Sn coils has been developed. The magnet provides a nominal field of 20 T with 13.2% load line margins at 1.9K with state-of-the-art superconductors, six-layer hybrid shell-type coil and cold iron yoke.

The HTS coil and the total coil cross-sections are noticeably reduced. The coil volume decrease and especially the HTS coil cross-section will allow reducing the cost of this 20 T hybrid dipole.

The stress management elements are being integrated to the coil cross-section to keep the mechanical stresses in brittle Bi2212 and Nb_3Sn superconductors below their dangerous level. Further magnet design optimization, including field quality, operation margins, stress level will be done in the next design study phase.

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