Electromagnetic and mechanical study for the Nb_3Sn cos-theta dipole model for the FCC

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Introduction

The INFN of Milan (L.A.S.A.) and Genova signed an agreement with CERN to construct the cos-theta dipole short model for hh-FCC. Here we present the first design of the magnet, which has one aperture of 50 mm and a cold mass of 750 mm diameter. The requirements adopted are the same set out by the EuroCirCol collaboration, keeping in mind that the main purpose of the model is to practise with the construction of a Nb_3Sn magnet, and therefore an higher priority is given to reach the target field of 14 T with the simplest design possible, giving less importance to the field quality.

Objectives

Magnet performance and field quality:

- Bore field 14 T;
- Margin of 14 % on the load line;
- Allowed high order harmonics < 30 units in modulus.

Mechanics:

- Maximum stress on conductors below 150 MPa at room temperature and below 200 MPa at cold;
- Stresses on mechanical structure below materials yield strength;
- No detachment between coils and pole.

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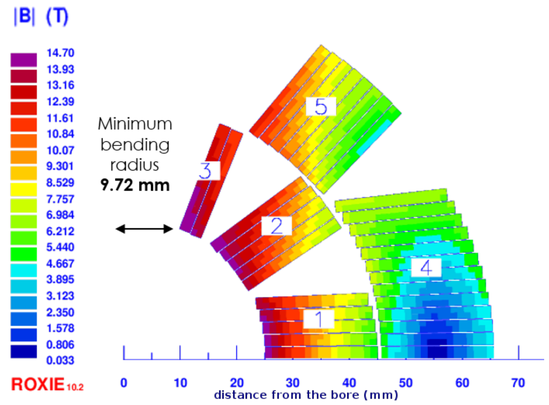
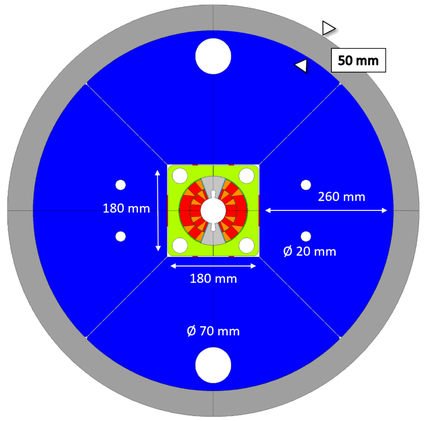
Electromagnetic Design

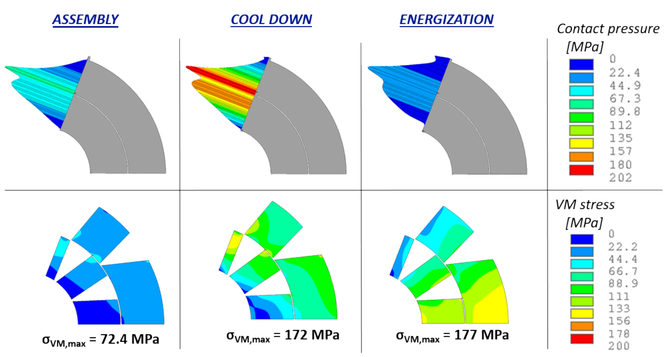
The magnet has five blocks of conductors spaced from each other with copper wedges, of which the minimum thickness is of 1.08 mm between the block number one and two. The minimum bending radius is found in correspondence of the block three as expected and is equal to 9.72 mm. The same layout has been studied using both the EuroCirCol target cable and the conductor under procurement at CERN (see Table 2).





Mechanical Design

The mechanical structure is based on Bladder & Keys technology to avoid cable degradation, maintaining stress on conductors below 150 MPa during assembly and below 200 MPa after cool down and energization. Furthermore, this system has the advantage of tuning simply the pre-stress only changing the key interference at room temperature, on the basis of the operating current chosen.



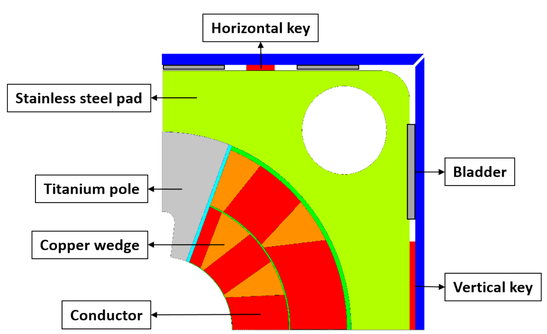


Table 1: High order harmonics at operating current.

Harmonics	b_3	b_5	b_7	b_9	b_{11}	b_{13}
Units	1.3	-6.2	18	2	1	-0.7

Table 2: Comparison between two different cable performances.

Conductor performance J_c (@ 4.2 K, 16 T)	Bore field (T)	Operating current (kA)	Margin on load line (%)
1500	14	25.0	14
	16	28.9	1.3
	16.2	29.3	0
1200	13.3	23.7	14
	14	25.0	9.5
	15.4	27.8	0

Design Parameters

Cold mass diameter	750 mm
Magnet length	1.5 m
Number of apertures	1
Bore inner diameter	50 mm
Maximum number of layers	2
Superconducting material	Nb_3Sn
Bore nominal field	14 T
Operation on the load-line	86%
Operating temperature	1.9 K
Nominal current	25 kA
J_c (@ 4.2 K, 16 T)	1500 A mm^{-2}
J_{Cu}	1547 A mm^{-2}
Stored energy	0.68 MJ m^{-1}
Field harmonics	≤ 30 units

Cable Parameters

Superconducting material	Nb_3Sn
J_c (@ 4.2 K, 16 T)	1500 A mm^{-2}
Filament diameter (μm)	20
Cu/Non-Cu	1
Number of strands	34 (2 × 17)
Strand diameter (mm)	1.1
Bare height (mm)	19.8
Bare inner width (mm)	1.892
Bare outer width (mm)	2.065
Insulation thickness (mm)	0.15
Keystone angle	0.5°
Twist pitch (mm)	100