ILSF BOOSTER MAGNETS FOR THE NEW LOW EMITTANCE LATTICE

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Abstract

Iranian light source facility is a 3 GeV storage ring with a booster which is supposed to work at 150Kev injection energy and guide the electrons to the ring energy 3GeV. It consists of 50 combined bending magnets in 1 type, 50 quadrupoles and 15 sextupoles in 1 family. Using POISSON, Ansys Maxwell and Radia codes, [1,2,3], two and three dimensional pole and yoke geometry was designed, also cooling and electrical calculations have been done.

INTRODUCTION

ILSF Booster is supposed to work at injection energy of 150Kev and lead the electrons to the ring energy E=3 Gev. It consists of 50 combined bending magnets in 1 type which provide horizontal focusing and correct natural chromaticity in addition to their bending role, 50 pure quadrupole magnets for vertical focusing and 5 defocusing quadrupoles for tune adjustment. There are also, 15 SF for correcting natural chromaticity and 5 SD defocusing sextupoles that each one is placed in each super period to correct eddy current effects. The dipoles are planned to be run in series with a common power supply and due to having one family of quadrupole and one for sextupoles, they will also be connected in series.

Booster H-type dipoles are combined function with a superimposed quadrupolar and sextupolar components in the dipole field by modifying the pole face geometry. Therefore, the magnet must be curved to match the beam orbit, so that the beam is always on the axis of the quadrupole and sextupole components. While, Booster quadrupoles and sextupoles ar e pure function magnets.

In Booster ring, where we have AC currents, Eddy currents are objectionable, not only because they decrease the flux, but also because they produce heat and a power loss proportional to i^2R, where i is the eddy current and R is the resistance of its path. [4, 5]. To avoid eddy currents, Silicon-steel 3% with lower electrical conducting should be used. So in ILSF booster yoke is considered to be a collection of M330-50A laminations, with nominal thickness of 0.5mm.

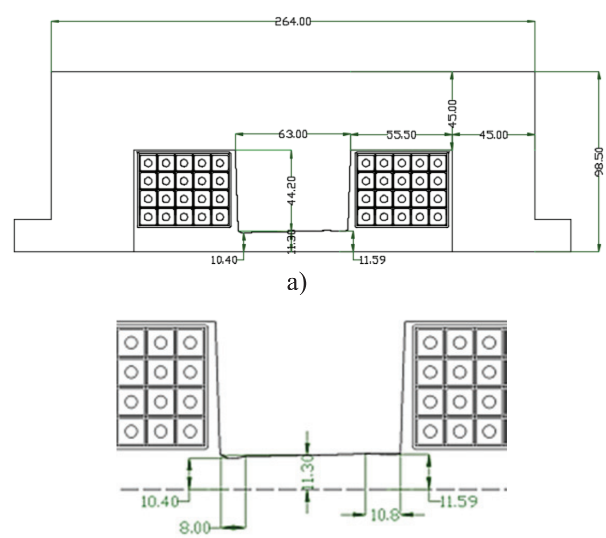
DESIGN OF BOOSTER MAGNETS

Dipoles

ILSF Booster dipole is combined H-type bending magnet having an imposed quadrupole and sextupole components with parallel-ends and a curved yoke. The specifications of the booster bending magnets is given in Table 1.

Table 1: ILSF Dipole Parameters (see Fig.1)

Parameter	**unit**	**Ext/inj**
Bending radius	m	10.34
Field	T	0.967/0.0483
Field gradient	T/m	-1.79
Sextupole component	T/m^2	-41.66
Half gap	mm	11.3
Magnetic length	m	1.3
Good field region	mm	±6
Number of turns per coil	-	20
Conductor cross section	mm^2	8.8 x 8.8
Cooling channel diameter	mm	4
Current	A	457
Current density	A/mm^2	7.04
Inductance	mH	3.8
Power consumption	KW	7.9
Number of cooling circuits	-	2
ΔT	°C	9
Water flow per circuit	m/s	1.15
Pressure drop	bar	6



b)

Figure 1: a) General dimensions. b) Pole profiles.

Also, Field tolerances are calculated to be less than 1×10^{-4} within the good field region ±6, Fig. 2.

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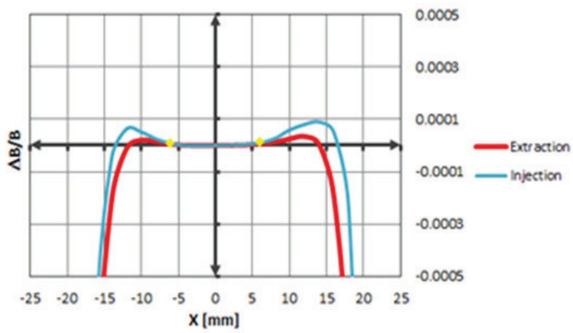

Figure 2: ILSF dipole field tolerances, blue line is for injection at 0.048T and red line indicates extraction field tolerances at 0.966T.

Although the two dimensional field may have the desired properties,3D design is necessary to study the longitudinal field distribution and end effects. 3D magnetic simulations of ILSF booster dipole have been carried out with ANSYS Maxwell software

The chamfers of the dipole's ends are to get the "same" effective length along the transverse, i.e. within ±6mm at two different extraction and injection excitations of the magnet. The optimized end chamfer is a 20mm cut that has 50 degrees in the ZY-plane and 2.5 degrees in the YX-plane. In order to investigate the integrated field quality at the beam pass limit, field integral is calculated at 10 trajectories by ±2mm parallel to the central one which is the actual beam trajectory. Therefore, integrated field tolerances at both injection and extraction can be obtained Fig. 3.

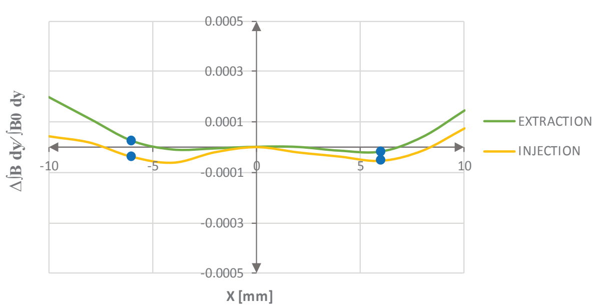

Figure 3: integrated field tolerances at GFR ±6mm; inject tion, yellow line and extraction, green line.

Moreover, differences between effective magnetic length for the two excitation levels, is obtained to be less than 0.1mm.

Quadrupoles

ILSF Booster has 50 quadrupoles with 18mm aperture, 15 cm length and 28cm ×28cm lamination cross section. The general layouts and length of all the quadrupoles are the same. Main parameters for these quadrupole are given in Table 2.

Table 2: ILSF Quadrupole Parameters

Parameter	unit	Ext
Aperture radius	mm	18
Pole tip Field	T	0.44
Field gradient	T/m	24.66
Magnetic length	m	0.15
Good field region	mm	±12.5
Number of turns per coil	-	15
Conductor cross section	mm^2	6.5 x 6.5
Cooling channel diameter	mm	3
Current	A	236
Current density	A/mm^2	6.7
Inductance	mH	1.42
Power consumption	KW	1.6
No. of cooling circuits	-	1
ΔT	°C	9
Water flow per circuit	m/s	2.7
Pressure drop	bar	6

Figure 4 depict field lines and dimensions of the ILSF quadrupoles. Also field quality for the optimized pole profile is calculated as shown in fig. 6.

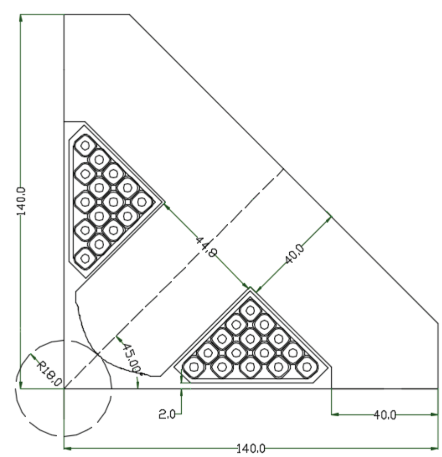

Figure 4: Dimension of ILSF quadrupole.

Field tolerances are less than 2×10^{-4} within the good field region ±12.5, Figure 5.

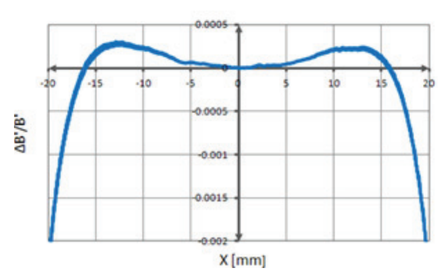

Figure 5: Booster Quadrupole field gradient tolerances versus x.

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ILSF booster quadrupole is simulated in 3D using both Radia and ANSYS Maxwell software. The optimized end chamfer is a 3mm cut that has 45 degrees in the ZY-plane. Integrated gradient tolerances are obtained to be less than 4 × 10^{-4} in the good field region of ±12.5mm.

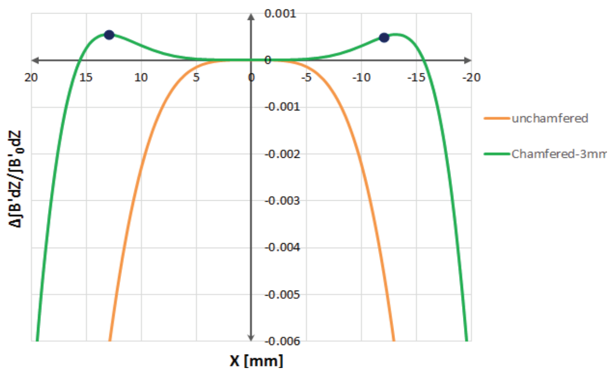

Figure 6: integrated field tolerances at GFR ±12.5mm; Chamfered, green line and unchamfered, orange line.

The optimization of the end chamfer is based on the minimum achieved value of the generated systematic multipoles at nominal excitation of the magnet. Figure 7 depicts absolute normalized integrated multipoles' errors at the good field region of 12.5mm before and after chamfering.

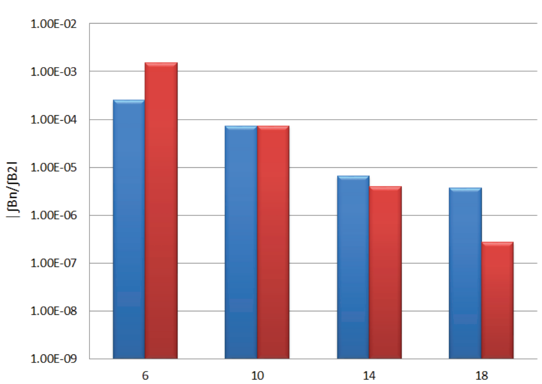

Figure 7: Absolute normalized integrated multipoles' errors @ 12.5 mm GFR with (blue) and without (red). Chamfer.

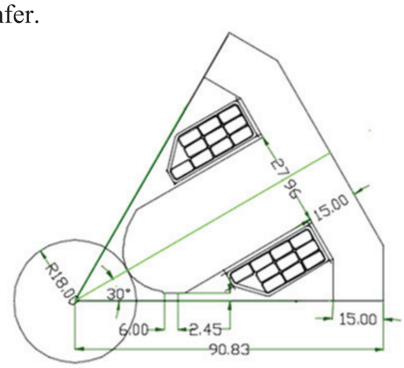

Figure 8: Dimensions, of ILSF Sextupole.

Sextupoles

ILSF Booster has 15 focusing sextupoles with 18mm aperture, 10 cm length and 18cm ×17.4cm lamination cross section. The general layouts and length of all the sextupoles are the same. Main parameters for the ILSF booster sextupoles are given in Table 3.

Table 3: Table 3 ILSF Sextupole Parameters

Parameter	unit	Ext
Aperture radius	mm	18
Pole tip Field	T	0.04
Field gradient	T/m^2	440
Magnetic length	m	0.10
Good field region	mm	±12.5
Number of turns per coil	-	10
Conductor cross section	mm^2	3.15 x 6.3
Current	A	36.9
Current density	A/mm^2	1.85
Inductance	mH	0.5
Power consumption	W	30

Also, field tolerances are obtained to be less than $5{\times}10^{-4}$ within the good field region ±12.5, Fig. 9.

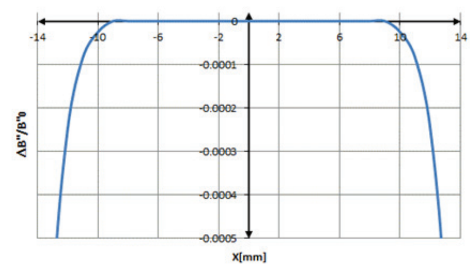

Figure 9: Sextupole component tolerances versus x.

CONCLUSIONS

The design of the booster ring magnets has been described. Magnets were designed for the critical parameters. Field uniformity of $\Delta B/B \le \pm 1 \times 0.01$ % in the dipoles, $\Delta g/g_0 \le \pm 2 \times 0.01$ % in the quadrupoles and, $\Delta S/S_0 \le \pm 5 \times 0.01$ % in the sextupoles at good-field regions are predicted.

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