TD-99-049
October 20, 1999

Comparison of Correcting Capability of Passive Correctors Based on a Thin Pipe and Thin Strips

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Abstract - Two types of passive correctors for correction of multipoles induced by coil magnetization in the Fermilab 11 T Nb3Sn dipole model have been proposed. This note presents the results of comparison of correction capability of thin pipe and strip type ferromagnetic correctors placed within magnet bore.

1. INTRODUCTION

Fermilab is developing a high field dipole magnet based on the Nb3Sn strand for future Very Large Hadron Collider [1]. Persistent magnetization currents in superconducting strands disturb the field in magnet bore at injection contributing to all multipole field components allowed by the coil symmetry (dipole, sextupole, decapole etc. for dipole coils). This effect is proportional to the critical current density in superconducting filaments, the effective filament diameter and the coil volume. A high critical current density, required to reach a high magnetic field at relatively small coil cross-section area, and a large effective filament size in commercially available now Nb3Sn strands lead to a quite high coil magnetization effect. This effect is much higher for Nb3Sn magnets than for NbTi accelerator magnets. The works aimed on the reduction of the effective filament diameter in Nb3Sn strands have been started. However, the required reduction of effective filament diameter by factor of 5-10 can lead to a significant increase of the strand cost. The attempts to compensate the coil magnetization effect in the superconducting accelerator magnets using specific features of magnet design were undertaken. A method used the passive superconducting coils placed in the magnet bore was proposed and tested on short NbTi dipole model [2-4]. Although this technique was never practically used in accelerators utilized the NbTi magnets, it could be very interesting and important for high field Nb3Sn accelerator magnets.

Recent interest to the passive correction of coil magnetization effect in Nb3Sn dipole magnet has led to the proposal of two new correction schemes. One of them is based on the thin ferromagnetic pipe placed inside the magnet bore to correct multipole components due to a difference in saturation (magnetization) in pole and mid-plane areas of pipe at low field. It was explicitly described in [5]. The main idea of another corrector type is to put the ferromagnetic strips in certain places within the magnet bore adjusted to produce multipoles with the same value as magnetization multipoles but with opposite sign so they cancel each other [6]. This note presents the results of comparison of the correction capability of those two correction schemes for compensation of the coil magnetization effect in the Fermilab Nb3Sn dipole model [1,7].

2. RESULTS AND DISCUSSION

The coil magnetization effect was calculated using OPERA 2D code. Superconductor magnetic properties were described by the B-H curve [6] obtained from the magnetization measurement of the internal tin (IGC) Nb_3Sn strand with the effective filament size of ~100 microns. Magnetic properties of the compensation pipe and strips were represented by the B-H curve corresponding to the HGQ (or MI) iron yoke.

Both the correction pipe and the correction strips were installed on the magnet beam pipe with the outer radius of 19.75 mm. For the correction pipe its correction strength was tuned by changing the pipe thickness. The correction strips have more free parameters for optimization, such as, number of strips, strip thickness, width and azimuthal position. The optimal number of strips and the optimal azimuthal strip positions were determined in [6]: two strips with 33.5-44.5 degrees (first strip) and 57.5-72.5 degrees (second strip) azimuthal position. Correction strength of the strip corrector was tuned also by changing the strip thickness.

The results of calculation of sextupole b3 and decapole b5 field components at low fields in second magnet excitation cycle before and after correction with correction pipe and correction strips are presented in Figure 1 and 2. Correction strip parameters were optimized to compensate (minimize) simultaneously b3 and b5. Taking into account that correction pipe has only one free parameter - its thickness, it was optimized for maximum compensation of b3 **or** b5. The effect on the other non-optimized harmonics (b5 or b3) in each case is also reported.

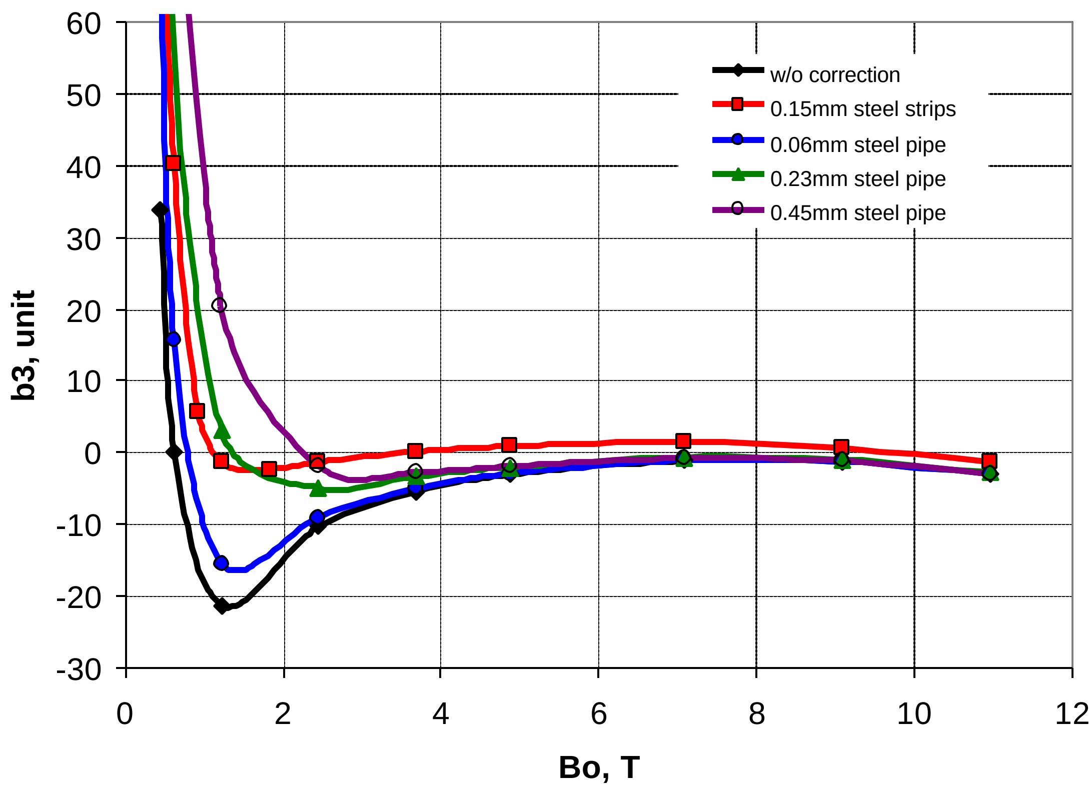

Figure 1: Sextupole field component before and after correction versus bore field.

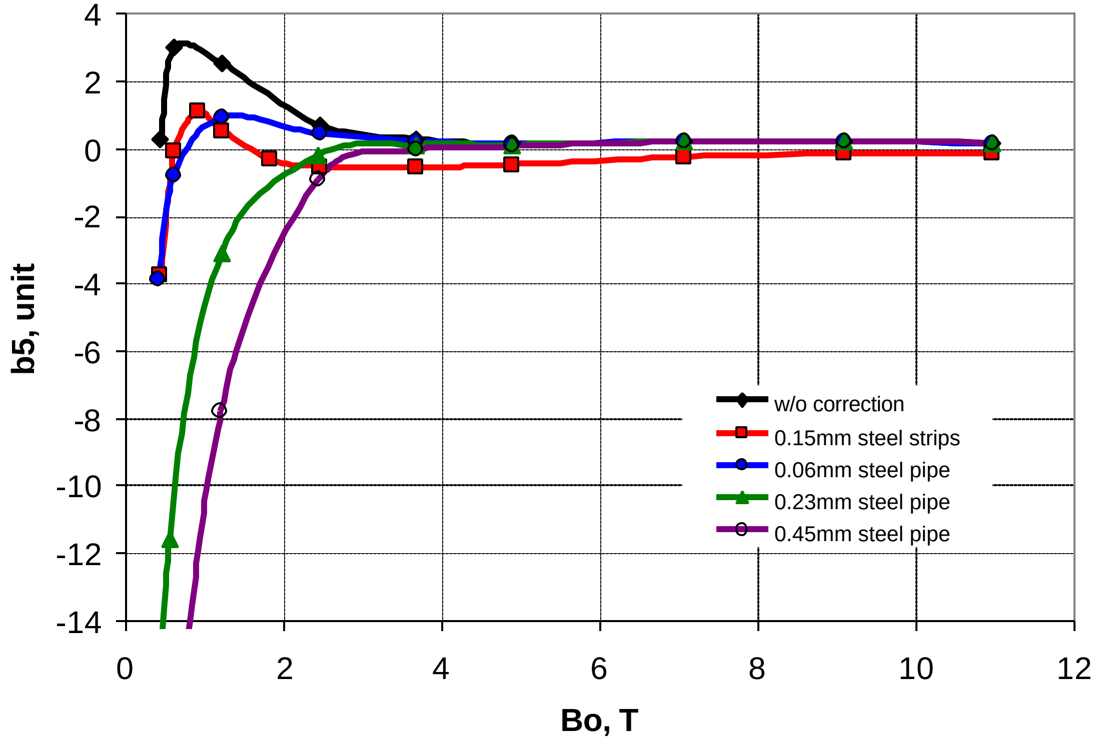

Figure 2: Decapole field component before and after correction versus bore field.

As it can be seen from the above plots, optimized correction strips allow one to reduce the coil magnetization contribution in b3 to ±2 units (or by factor of 10), and in b5 to ±1 unit (or by factor of 3) for magnetic fields in the bore >1 T. One can also see that the strip corrector significantly increases the magnet dynamic range even at quite large effective filament diameter in the Nb3Sn strand.

The optimized 0.23 mm thick correction pipe allows one to restrict the sextupole field component b3 only to ±5 units in the same field range as above, but the decapole component b5 at the same time significantly deteriorates. And vice versa, an optimal compensation of b5 using the 0.06 mm thick pipe does not allow one to achieve the desirable reduction of b3.

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