B R O O K H A V E N   N A T I O N A L   L A B O R A T O R Y

MAGNET DIVISION NOTES

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Date: July 26, 1991

No: 388-1 (SSC-MD-268)

Task Force: Coil Geometry

Title: Random a_1 Correction in SSC Dipoles

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Random a_1 Correction in SSC Dipoles

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From the beam dynamics considerations it is desirable that the RMS variation of the unallowed harmonic a_1 (skew quadrupole) is $\frac{1}{2}$ unit, instead of the given specification of $1\frac{1}{4}$ in SSC dipoles[1]. The current specification is what can be reasonably achieved in these magnets based on the the experience with the similar magnets made for the other particle accelerators.

In this note we present a simple method to correct the a_1 caused by the practical limitations in the manufacturing process of the coil. We propose that the up-down magnetic asymmetry of the collared coil be compensated by the up-down asymmetry in the magnetic length of the yoke laminations. To determine the difference in the amount of magnetic laminations to be used in the top and bottom half of the magnet, one would measure this harmonic in the collared coil at room temperature. In this note we shall numerically discuss this method in the BNL design of the SSC 50 mm magnet which uses horizontally split yoke and where the cross section of the low carbon steel laminations (magnetic) used in the straight section and of the stainless steel laminations (non-magnetic) used in the magnet ends are identical. This scheme can be incorporated in a vertically split yoke (Fermilab design) also where one would switch from vertically split yoke to horizontally split yoke in a small region where this correction is to be adopted. It may be pointed out that in the magnet ends (the place where we are proposing this correction to take place), there is a transition from the low carbon steel laminations to the stainless steel laminations.

Our preliminary estimates (presumably correct within a factor of two) based on 2-D calculations, show that to correct 1 unit of a_1 one would need to switch 1 inch of the magnetic laminations with the stainless steel laminations in the two ends of the magnet. Locally, this creates 200 units of a_1 with respect to the central field there (which is 85% of B_0 in the magnet straight section). The schematic of adopting the above correction in a magnet is shown in figure 1. The total amount of either the stainless steel or the low carbon steel lamination does not change in the process. There would be theoretically no change in the allowed harmonics, except for the end effects, which should be quiet small as compare to the specifications given for them. Other non-allowed harmonics introduced in the process, for example a_3, etc., are $\sim$ .01 unit or less – well within the specifications for them. There would be some loss in the a_1 correction at high field due to iron saturation, however, at 6.6 tesla $\sim$ 90% of the correction would still be in effect. This should be a relatively easy thing to implement with practically no deterioration in the mechanical property of the magnet. In a large scale industrial production environment it may, for example, be implemented in the following manner:

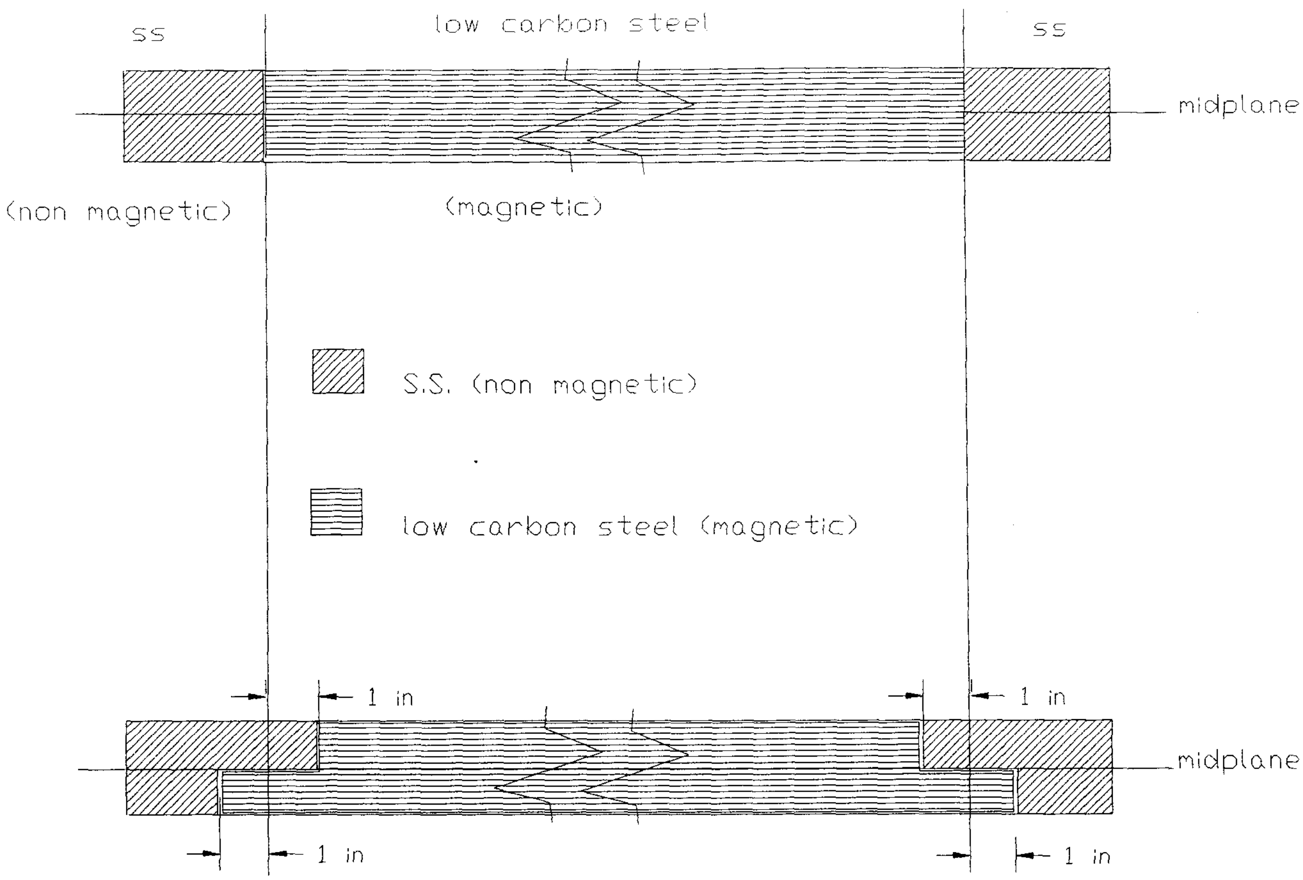

Figure 1: Re-assignment of the location of magnetic and non-magnetic laminations to correct a_1 (skew quadrupole). In SSC 50 mm magnets, a rough estimate shows that moving $1''$ of laminations from top to bottom in both ends would fix about one unit of a_1 integrated over the length of the long magnet.

- Make $\frac{1}{4}$ inch thick blocks of laminations (usual thickness 3 inch).
- Paint low carbon steel and stainless steel laminations differently. Note that the amount of the two types of laminations to be used in any magnet is independent of the amount of a_1 correction to be applied.
- Each $\frac{1}{4}$ inch block in one end corrects $\frac{1}{8}$ unit of a_1. Decide the amount of the two painted laminations to be distributed in the top and bottom halves of the magnet based on the measured a_1 in the collared coil. Note that if a_1 is measured 0 then the paint will change at the same axial location in the top and bottom half of the magnet.

In the BNL long/short 50 mm dipole design, the length of the coil straight section is $\sim$ 585/53.5 inch, the length of the space occupied by the low carbon steel laminations is $\sim$ 581.6/50.7 inch and the length of the space occupied by the stainless steel laminations in the two ends is $\sim$ 5.8 inch in each end.

A 3-d calculation would make a better determination of the amount of laminations to be switched between the top and bottom halves to create a desired a_1. However, in any case a measurement is required to check the validity of any such calculation. Fortunately, to carry out this test in a 50 mm dipole, all hardware is in place at BNL for this purpose. One can rebuild one of the 50 mm short magnet by replacing one $3''$ low carbon steel magnetic lamination block with one $3''$ stainless steel lamination block. The harmonics in the end regions must be measured in both cases – i.e., before the re-built and after the re-built – to determine the net change in a_1 caused by asymmetric yoke. It would be better to have two different lengths for yoke asymmetry (magnetic) in the two ends of the magnet to get one more data point to verify the 3-d calculations.

The best experiment in any end would have a few $2''$ blocks of laminations specifically made for this purpose. One would replace one $3''$ block each of low carbon steel and stainless steel laminations from both top and bottom halves of the magnet from the location where this transition from magnetic laminations to non-magnetic laminations takes place. Then one would put at the top one $2''$ block of low carbon steel plus two $2''$ blocks of stainless steel and at the bottom two $2''$ blocks of low carbon steel plus one $2''$ block of stainless steel laminations. It would create the case when $1''$ of magnetic laminations are moved from top to bottom. This would check the extent of cancellation of the allowed harmonics (b_2, etc.) between the top and bottom half of the modified ends when the total mass of the magnetic laminations is kept the same.

References

1. R. Stiening , Private communication.