BROOKHAVEN NATIONAL LABORATORY

MAGNET DIVISION NOTES

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Title: A Possible Approach for Designing an Iterated Cross Section which is Independent of Pole Compression, etc.

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A Possible Approach for Designing an Iterated Cross section which is Independent of Pole Compression, etc.

R.C. Gupta

1. Introduction

In RHIC dipole the plastic spacer compresses towards the pole together with the coil compressing in the azimuthal direction towards the midplane in the cross section. Moreover, the amount of pole compression is somewhat unknown which makes it difficult to exactly locate the position of the pole in a coil in an actual magnet. The exact location of the pole is required to compute the field harmonics in the magnet and to compute the pole location in the iterated design for the next series of magnets. This compression was not included in the original magnetic design calculations but since they seem to better corelate the the calculations and measurements (at least in the magnet DRS005) it would make sense to include them in future analysis. This, however, appears to bring more confusion in the process of empirically removing the unexplained measured harmonics (in the next series of magnets) which were not predicted by the calculations.

In this note we propose a possible approach for designing an iterated cross section which is independent of the amount of pole compression and other similar effects as long as the amount of them is not changed in the next series of magnets. The approach calls for bringing a relative change in the pole angle and all other related parameters and continue doing drawings, etc. based on no pole compression even if it is included in the magnetic and mechanical analysis. This assures and requires that we continue to carry the process forward in future just as we have been doing in the past.

This note may discuss things of a trivial nature but is formally written here since a significant amount of confusion has been caused by them. The approach should work as long as the amount of pole compression is small, which is the case here.

2. The Procedure

Let us assume the following :

1. Pole angle in the drawings for original 9B84 cross section, where no pole compression was assumed = θ degree
2. Original pole angle in the coil molding fixture = ϕ degree
3. Amount of pole compression = x mil
4. Change in pole angle due to change in insulated cable thickness = y mil
5. Difference between the design (nominal) shim and the actual shim used in the magnet (this may include pole compression) = z mil

Note that the above means the following for the original 9B84 design (as per the design cable):

CASE A

1. Pole angle in the magnet with **no** pole compression = θ
2. Pole angle in the magnet with pole compression = θ + x
3. Whether there is a pole compression or not the pole angle in the coil molding fixture is always = ϕ
4. If there is no pole compression then z = 0; with pole compression z = x

However, in the actual magnet (say DRS008), where the insulated cable thickness deviates from the design value, we have the following :

CASE B

1. Pole angle in the magnet with **no** pole compression = θ - z
2. Pole angle in the magnet with pole compression = θ + x - z
3. Whether there is a pole compression or note the pole angle in the coil molding fixture is = ϕ - z
4. If there is no pole compression z = -y; with pole compression z = -y + x

Let us make our target in the iterated design to be "change the pole angle so that we get back to a pole angle where the nominal design shim can be used", i.e, change pole angle by an amount = +z. The same general procedure will follow even if the target change in the pole angle has some other value.

In an iterated design which is based on the cable used in the previous magnets and the above change in pole angle, we shall have the following :

CASE C

1. Pole angle with no pole compression = (θ - z) + z = θ
2. Pole angle with pole compression = (θ + x - z) + z = θ + x
3. Pole angle in the coil molding fixture = (ϕ - z) + z = ϕ
4. Amount of shim over the nominal shim, z = 0, whether there is a pole compression or not

Note that we are back to the original pole angle of CASE A. Moreover, the expected shim in the iterated design should be of nominal size whether there is a pole compression or not. That means that we have empirically removed (compensated) the mechanical effect of pole compression from the iterated cross section in the next series of magnets.

Now we shall show that following the same procedure the unexplained differences between the calculated and measured field harmonics would be empirically removed irrespective of the amount of pole compression.

The ground rules to follow are, (a) The pole compression should be taken out from the analysis before the coordinates are sent to drawing office, i.e., send coordinates for the no pole compression case. This was being done before also. (b) The same (x) amount of pole compression should be used in comparing the calculations versus measurements and in arriving to an iterated design.

Let us assume the following for any i^{th} harmonic :

1. Value in the original 9B84 cross section (no pole compression) = $(b_i)_o$
2. Value due to x mil of pole compression = -$(b_i)_x$
3. Total value after pole compression = $(b_i)_o$ - $(b_i)_x$
4. Computed value after including the differences between the nominal shim and actual shim (z) in the magnet with no pole compression (pole angle θ - z) = $(b_i)_c$
5. Computed value of above after including the x mil pole compression (pole angle θ - z + x) = $(b_i)_c$ -$(b_i)_x$
6. Measured value in an actual magnet = $(b_i)_m$

This means that the differences between the measurements and calculations are :

1. For no pole compression case = $(b_i)_m$ - $(b_i)_c$
2. For x mil pole compression case = $(b_i)_m$ - $(b_i)_c$ + $(b_i)_x$

Now we design an iterated cross section to empirically remove the differences between the computed and measured harmonics. We shall show that although we designed it assuming no pole compression in the magnet, it will work even if there was a compression. To achieve this, the target for i^{th} harmonic should be -[$(b_i)_m$ - $(b_i)_c$].

This means that in the next series of magnets we expect the following after accounting for the unexplained differences in the i^{th} harmonic :

$\{ -[(b_i)_m - (b_i)_c] \} + \{ [(b_i)_m - (b_i)_c] \} = 0.$

Now let us examine the above cross section in case of a pole compression. If the pole compresses by x mil, the target harmonic in the iterated design would actually be $\{ -[(b_i)_m - (b_i)_c] - (b_i)_x \}$. Since the unexplained difference between the calculations and measurements are expected to remain the same as they were before in the pole compression case, we expect the magnet to have the following value of i^{th} harmonic :

$\{ -[(b_i)_m - (b_i)_c] - (b_i)_x \} + \{ (b_i)_m - (b_i)_c + (b_i)_x \} = 0.$

This demonstrates that this approach works independent of the amount of pole compression.

3. Conclusion

The approach discussed here, can be used to obtain zero harmonics and zero shim in an iterated design irrespective of the value of pole compression, etc. Moreover, a relative change in the pole angle in various parts is independent of the actual amount of pole compression. One can and <u>must</u> continue to use the past practices of doing design and manufacturing if this approach is to work.