EFFECT OF RANDOM CONDUCTOR THICKNESS ERRORS ON MAGNETIC FIELD QUALITY: SSC RING DIPOLE MAGNETS

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We assume that each conductor as seen in the first quadrant of the magnet cross section, has a thickness (azimuthal dimension) equal to the nominal value plus an error. The errors are random; the distribution is unimportant. The pole edge and midplane edge of each layer of the coil is fixed; the effects of errors in the positions of those boundaries is considered elsewhere. The elastic moduli of the conductors are alike; the elastic modulus of the spacers between blocks of conductors ("wedges") is infinite. The conductor-to-conductor variation in thickness results in a readjustment of the position of each conductor, and that in turn generates errors in the magnetic field. In the SSC magnets, the conductors do not lie along radial lines. For the purposes of this study, however, the conductors have been assumed to be radial. The field errors for the two layers are added in quadrature. The errors for the entire cross section are obtained by simply doubling those determined for one quadrant. The theory is presented in Reference 1. The results of the study are presented in Table 1.

For the method of analysis to apply, a conductor has a certain thickness throughout the length of the magnet, then the thickness changes to a different value for the return half of the turn, then changes again for the next half turn, and so forth. Not very likely! However, if we postulate that the distance over which the thickness changes from one value to another is, say, one ninth of the length of the magnet on average, then it seems legitimate to say that the effect is a third as much, r.m.s.-wise, as if the thickness suddenly switched every half turn. On the other hand, if the pitch of the thickness variation were greater than the magnet length, on average, and varied randomly, then there would be no direct correlation between the conductor thicknesses on one side of the magnet with those on the other, and the calculated results would apply directly.

So, how does this tie in with specified tolerances? We might postulate that the pitch of the thickness variation is very small compared to the magnet length, and so the effect on field is much smaller than that obtained by direct calculation. However, what counts is not what is postulated; what counts is what is specified. The specifications don't require the pitch to be short; the only reasonable assumption is that the pitch is long, and so the results are applicable.

TABLE 1.
SENSITIVITY OF MAGNETIC FIELD MULTIPOLE COEFFICIENTS
TO RANDOM ERRORS IN CONDUCTOR AZIMUTHAL THICKNESS

Sensitivities are normalized to the dipole field, and are expressed in "units" per 0.001 in. of rms thickness error. A "unit" is 1/10,000 of the dipole field.

Multipole order	Real Skew	Imaginary Normal
Dipole	3.813	2.309
Quadrupole	1.369	2.230
Sextupole	0.6481	1.124
Octupole	0.3947	0.4335
Decapole	0.1767	0.1772
12-pole	0.07420	0.07432
14-pole	0.03183	0.03137
16-pole	0.01398	0.01349
18-pole	0.00540	0.00666
20-pole	0.00241	0.00297
22-pole	0.00123	0.00123
24-pole	0.00055	0.00060

REFERENCE

1. Effect of Random and Systematic Conductor Thickness Errors on Magnetic Field Quality, R. B. Meuser, October 15, 1987. SSC-N-394.