MEASUREMENT OF THE TITANIUM VACUUM CHAMBER EDDY CURRENT FIELDS AND POLE FACE WINDING CORRECTIONS FOR THE ZERO GRADIENT SYNCHROTRON (ZGS)

E. Crosbie, T. Khoe, E. Berrill, T. Hardek, and R. George
Argonne National Laboratory
Argonne, Illinois

Summary

The titanium vacuum chambers (TVC) which will be installed in the ZGS are equipped with pole face windings for correction of the eddy current fields. A prototype of the chamber and correction windings has been installed in a spare magnet block test fixture for measurement of the eddy current fields as a function of radial position and time. The ten difference signals from 20 test coils are read into a SEL-810A computer. The computer displays the measured gradient on a scope, either as a function of radial position at a selected time during the magnet pulse or as a function of time at a selected position. Thus, the result of applying compensating pulses to the pole face windings can be shown directly.

Pole Face Winding Description and Controls

The pole face windings contained in the ribs of the new TVC for the ZGS are designed to compensate for expected eddy current sextupole field errors of about 0.11 G/in² over a radial aperture of about ±15 in. In order to maintain the betatron tune values to within ±0.025, it will be necessary to correct the field gradient over the required aperture to within ±0.02 G/in at the injection field of 480 G. As the field rises during acceleration, the permissible gradient error increases linearly with the field.

The pole face windings used to make the eddy current corrections are spaced 1.5 in over the range ±10.5 in and 0.75 in apart from there to ±15.75 in (Fig. 1). The currents in the pole face windings are in opposite directions on the inside and outside halves of the chamber with the corresponding return windings also on the inside and outside edges of the chamber.

The magnitude of the sextupole field errors produced by the eddy currents in the iron and vacuum chambers is proportional to the rate of rise of the magnetic field B. The time constants are about 200 μs for the vacuum chamber and about 50 ms for the iron. The contribution to the total field error is about the same from each of these sources. In addition, there is a nearly constant negative sextupole error field trapped in the iron at low fields due to reverse eddy current loops as the magnetic field decays from the saturation condition at flattop. (This is called the residual field error.) In order to correct for all of these errors as a function of time, the control circuits have been designed so that the current $I_j$ in each pole face winding has the functional form

$$I_j = G_1 B(t) + G_2 a_j$$

Current regulator circuits for each coil maintain the desired distribution of currents in the individual windings during the pulse (Fig. 2). Potentiometers, $b_j$ and $a_j$, for each winding control the distribution of currents required to correct for the eddy current and residual field errors respectively. A function generator $f(t)$ supplies a controlled mixture of two exponential functions with adjustable time constants. The B input is supplied by a pickup loop around the magnet test fixture (on one octant when installed in the ZGS). $G_1$ and $G_2$ are adjustable to give the required level of the two kinds of corrections. Most of the power for the eddy current correction coils is supplied by the voltage induced in the separate windings. Those windings, near the inside and outside, which do not have sufficient induced voltage have additional power supplies.

Fig. 1 Partial View of Chamber with Pole Face Windings and Returns

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Test Fixture Measurements

A prototype of the TVC, with pole face windings and correction control, was installed in the ZGS spare magnet block test fixture. Using the signals from 20 search coils spaced 1.5 in apart (Fig. 1), we were able to measure the radial distribution of gradients as a function of time while pulsing the test fixture and to demonstrate that the corrections could be made.

The gradients were obtained by subtracting the signals from adjacent search coils to produce ten ΔB measurements across the chamber. These ten signals were stored in the on-line SEL-810A computer, which calculated the gradients and displayed the results. The results were shown either as a function of position for any desired time during the pulse or as a function of time for any of the ten positions. The search coils could be shifted radially by 1.5 in between each pulse so that it was possible to record 20 gradient measurements (at 1.5-in intervals) across the chamber every two pulses. In addition, the shifting of the search coils was used to measure residual field gradients for 20 radial locations. The programming software also provided for averaging the data over many pulses and fitting calculated curves to the final results.

Our data acquisition system is capable of reading 0.005 G/count. The timing error is less than one part in 10^6. In order to demonstrate that the corrections could be made to the desired accuracy, the search coil areas had to be the same to within 0.003%. Comparison of the difference signals from alternate search coil pairs for the same radial location demonstrated that the required coil matching was achieved.

Figures 4 and 5, which show the corrected and uncorrected gradient measurements as a function of position at 800 G and as a function of time at radial position -9.75, are typical of the results. By reducing the scale of the corrected results we were able to demonstrate that the gradient errors could be measured and corrected to within the required accuracy up to a main magnetic field strength of about 2 kG.

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References
