DEVELOPMENT OF A 100 MM PERIOD HYBRID WIGGLER FOR THE AUSTRALIAN SYNCHROTRON PROJECT

Joe Kulesza, Eric Johnson, Dave Waterman, Alex Deyhim, Advanced Design Consulting USA, 126 , Lansing, NY 14882
Chris Glover, Australian Synchrotron Project, Australia
K. Ingvar Blomqvist

Abstract

This paper summarizes the final magnetic measurement for a hybrid wiggler shown in Figure 1 installed at the Australian Synchrotron Project (ASP). This device uses an anti-symmetric, hybrid design with a period of 100 mm and 40 full-strength Vanadium-Permendur poles surrounded by Neodynium-Iron-Boron magnets (see table 1 for wiggler specification). It is designed to operate at two gaps with critical energies of 11.4 (14mm) and 9.6 keV (18.16mm) and to have a maximum gap with the field strength $B_y \leq 50$ G. The wiggler's drive mechanism is capable of moving from minimum to maximum gap in 96 seconds. Table 2 shows minimum gap fourier analysis.

End terminations are designed to maintain the electron trajectory on-axis. The straightness of the electron orbit is controlled by moving the poles vertically and horizontally. The integrated multipoles are controlled over the interval $|x| < 25$ mm and all gap sizes by moving the side magnets, installing correction magnets at the wiggler entrance and exit and using correction coils. All adjustments have been made using threaded fasteners. No shims have been used.

Figure 1: 100 mm Period Hybrid Wiggler

The Australian Synchrotron is a 3GeV third-generation synchrotron, circumference 216 meter, and current 200 mA shown in figure 2.

Figure 2: The Australian Synchrotron Facility

Table 1: Wiggler Specification

Wiggler Type	Hybrid
Wiggler Symmetry	Asymmetric
Number of Full Size Poles	40
Total Number of Poles	42
Length of Magnet Assemblies	2065.2 mm
Total length of Wiggler	2105 mm
Minimum Gap	14 mm
Maximum Gap	200 mm
Peak Field at Maximum Gap	< 0.005 T
Magnet Block Remanence Used In Calculations	1.25 T

Table 2: Minimum Gap; Fourier Analysis

1st Harmonics	1.644 T	
3rd Harmonics	0.265 T	
5th Harmonics	0.029 T	
7th Harmonics	-0.006 T	
9th Harmonics	-0.006 T	
11th Harmonics	-0.002T	
Peak Field	1.923 T	
Effective Field	1.646 T	
Higher Order Contribution in Magnetic Field	16.2%	
On Axis Critical Energy	11.6 keV	
Magnetic Force	108 kN	
Magnet Material	NEOMAX-40NH	NEOMAX-42AH
Minimum Remanence	1.25 T	1.28 T
Typical Remanence	1.31 T	1.34 T
Minimum Intrinsic Coercivity	5 kOe	24 kOe

INTEGRALS AND MULTIPOLES

Integrals were measured using the flip-coil. While the horizontal integrals were always found to be within the specified limit of ± 100 +150 |x| G-cm, the vertical integrals varied significantly at gaps of more than 20 mm, requiring the vertical dipole correction coils to be used to meet the specifications. In order to better quantify the rapid change in the normal integral, data were collected at a large number of gaps between 14 and 60mm. These data are plotted in figure 3.

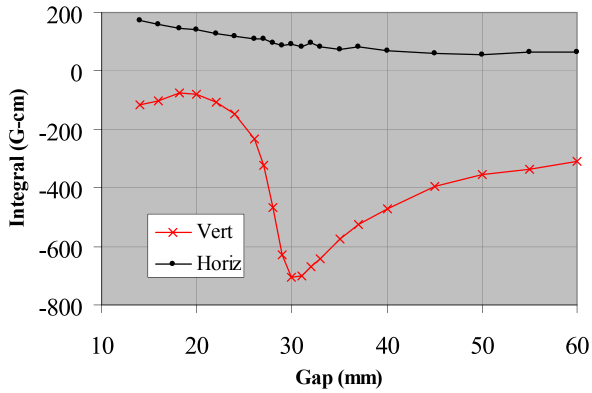

Figure 3: On-axis field integrals for the wiggler. No background subtraction.

As noted previously, deformation of the wiggler frame is strongly affected by the design of the compensation springs. The x and y-position of the magnetic centerline, its pitch and roll, can be affected by non-uniformity of the compensation springs. The magnetic centerline was measured at six additional points from 20 to 50 mm, which are shown in Figure 4, in order to determine whether the spring design was affecting the vertical integrals. A cubic fit to these points, shown in black, shows that the greatest change in the centerline position occurs at a gap of 30mm, suggesting a correlation between the changes in the normal integral and the centerline position.

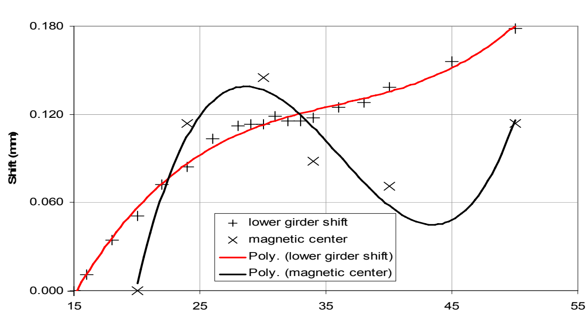

Figure 4: vertical movement of the lower magnet girder as a function of gap.

Also plotted in the figure are measurements of the lower girder position relative to the Hall-probe bench, made using a dial indicator. Here the plot shows the difference between the expected position and that actually measured as the gap is increased from14mm to 50mm. As the gap increases, bending in the frame relaxes, shifting both girders upwards. An inflection point can be seen at a gap of about 30mm that coincides with the shift seen in the centerline. The spring stiffness also changes at this gap and is the likely cause of this behavior.

Repeated measurements of the girder position showed that position is absolutely repeatable within the resolution of the dial indicator, < 12.5 µm.

Multipoles. Multipoles were measured over a range of gaps from 14 to 40 mm and at 206mm using the flip-coil system. Data were taken over a span of ±25mm about the magnetic centerline using 2.5mm intervals. Multipoles were calculated over a range of ±20mm, using the equations for $\int B_y$ and $\int B_x$. A 9th order polynomial fit was used.

Multipole terms usually decrease with increasing gap but not in this instance. Once again, a rapid change occurred at a gap of about 30 mm. These changes were not, however, sufficient to exceed the specification limits after correction magnets had been added. Example of measurement results are given in Figure 5. It is important to note that the tabulated dipoles may not exactly match the measured integrals. This is a function of the quality of the polynomial function used to fit the data. All of the multipoles were within specification limits.

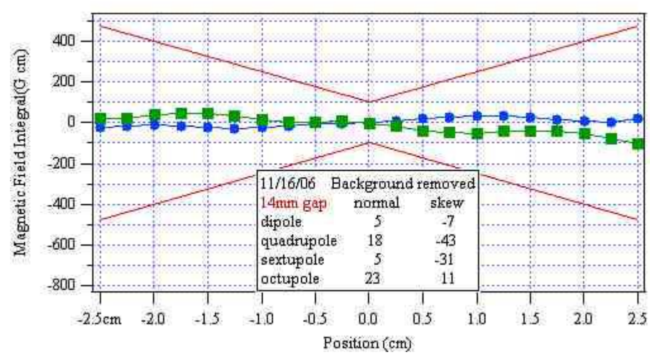

Figure 5: Multipoles measured at gap 14mm. Vertical 1st integral correction coils were used. The background field has been removed. Skew integrals are shown in green, normal in blue.

CORRECTION COILS

Four sets of correction coils were added to the wiggler to correct normal and skew 1st and 2nd integrals. Only the vertical coils were required in order to bring the integrals into spec.

The vertical coils are 14 AWG multi-strand copper with color-coded, Kynar insulation. The coating used to apply the color to the insulation is extremely fragile and flaked off during winding of the coils. Careful inspection showed that the clear Kynar insulation had not been damaged. No shorts could be detected when probing the leads. Horizontal coils were wound using 18 AWG multi-strand copper with polyimide insulation.

The vertical coils were attached directly to the magnet holders and moved as the gap is changed. Although the spacing between the pairs of coils increases with the gap, the field decays relatively little. At the maximum gap the

1-4244-0917-9/07/$25.00

field is still more than a third of that produced at a gap of 14 mm.

ELECTRON ANGLES, TRAJECTORIES AND 2ND INTEGRALS.

Using the Hall-probe, the B-fields were scanned along the magnetic axis with samples taken at 1mm intervals. Data were collected along a 3.5m path starting and ending well beyond the extent of the wiggler's magnetic field (B_y « 10 G). Repeatability were shown to be everywhere better than ± 3 G over five scans.

Since drift and the planar Hall effect are persistent problems with Hall-effect sensors the flip-coil results were used to correct the data. Background integrals were subtracted from these results. Electron angles calculated from the measured B-fields were corrected within B2E so that the exit angle matched the integral measured by the flip-coil

After calculating the electron angles the trajectories and 2nd integrals were determined within B2E. Plots of electron angle and trajectory are shown in Figure 6 for the minimum gap. Pole strengths are shown as vertical bars and reference the right-hand scale. The spacing between poles 2 and 39 was used to calculate the period, which was found to be 100.21mm. The average peak field is 1.902 T, which gives a k-value of 17.8. The variation in the peak field is 1.3%, less than the specified upper limit of 2%.

MAGIC FINGERS

Magic fingers were used to correct the dipole and quadrupole moments of the undulator. Vertical correction magnets were inserted with a positive sign indicating a field directed upwards at both upper and lower girders (antisymmetric in y). Horizontal correction magnets were installed with positive upwards on the upper magnet array and positive downwards on the lower magnet array (symmetric in y). All of the ASP's magnetic and mechanical specifications were met.

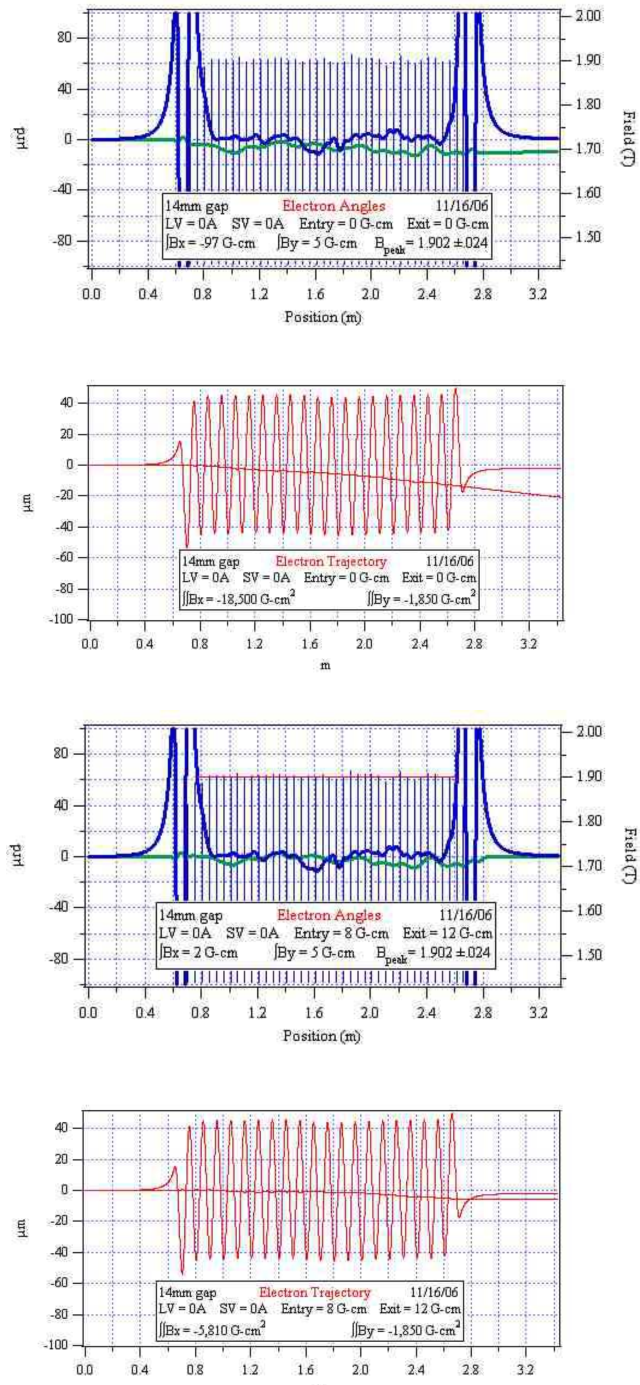

Figure 6: Results for the wiggler at minimum gap (14 mm). At top the electron angles and trajectory (bottom) without the use of correction coils. At bottom, electron angles and trajectory with horizontal coils (*simulated*).