Magnets, Power Supplies and Alignment

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Operation experience of the SPring-8 Storage Ring over the last year -- and, in particular, the achievement of a small closed orbit distortion -- has confirmed the accurate alignment and high performance standards of its magnets.

1. Magnets

Tune

Differences between the predicted and measured tune values are 0.1% and 0.8% respectively in the horizontal and vertical directions. The horizontal tune error can be explained by factors such as quadrupole magnet power supply setting, quadrupole magnet field strength error, and tune shift from sextupole magnetic fields; but the vertical difference is slightly larger than would be expected from these sources of error[1]. However, both horizontal and vertical error values are small and have no effect on normal beam operation.

Beam Energy and Energy Loss

Beam energy and energy loss are calculated from measurement results of bending magnet field distribution. Calculated beam energy and energy loss are 7.975 MeV and 8.91 MeV/turn respectively, whereas the design value of energy loss at 8 MeV is 9.23 MeV/turn. The energy loss is 3.5 % lower than the design value as a result of lower beam energy and bending magnet field distribution, which has a tail rather than a hard edge. These values are consistent with the RF parameters related to the synchrotron tune.

Magnetic Field Interaction between Magnets

When the sextupole magnet strength was varied to adjust chromaticities to their original values, the closed orbit differed 0.12 mm from its pre-adjustment value. Since the usual reproducibility is less than 0.02 mm, this value was unusual. The sextupole magnets were initialized but the reproducibility did not improve. After initializing the steering magnets, the closed orbit distortion returned to its normal level. As the nearest magnet to the sextupoles are the horizontal steering magnets, we suspected that sextupole magnet fields affect steering magnet fields. We determined a sequence for initializing magnets and use this when varying magnetic field strengths[2].

2. Power Supplies

During 1997, there were nine occasions when power supply problems caused the suspension of beam operation. In five cases, the power supply recovered immediately, but the remaining four incidents interrupted beam operation for more than one-hour. Three of the latter incidents took place during ring commissioning but one occurred in user time, causing a 12 hour suspension of beam operation.

Three incidents which occured during the commissioning time were due to temperature rise. When warmer weather caused the temperature in the power supply room to reach 42 ℃, power supplies to the bending, quadrupole and sextupole magnets became unstable or failed. Consequently we: (I) replaced the power supplies’ temperature-sensitive components with devices that remained stable at higher temperatures; and (ii) installed air conditioning in the power supply room.

The beam interruption incident during user time was caused by a damaged capacitor in a sextupole magnet power supply. We inspected the capacitor in the other six power supplies and found that they were swelling. As a precaution, we replaced all capacitors and are currently investigating the cause of damage.

To guard against the risk future problems causing long periods of beam down-time, we plan to construct a back-up power supply that can be switched to quadrupole, sextupole magnets.

3. Alignment

Measured closed orbit distortions without correction were less than 5 mm and agreed with the calculated values based on the alignment results[3]. And the measured coupling coefficient was less than 1 %[4]. These results confirm that the magnets are aligned accurately [5][6].

Levels between the girders were measured during the summer and the winter shutdown periods. There were no large variation except in 11 locations where there are structures below floor level (namely an access underpath, five drainpipes, and five RF wave guide rooms). These floor areas are sensitive to vertical movements caused by atmospheric temperature variation[5].

4. Beam Stability

Fluctuation of Cooling Water Temperature

The magnets were cooled by the water maintained at a temperature of 30±1℃. Normally the fluctuation in cooling water temperature is less than±0.2℃ but there are occasional variations in excess of ±1℃[7]. Figure 1 presents the results of our investigations into the effects of temperature variations beam orbit. This shows that even variations with the ± 1 ℃ range affect the horizontal beam orbit[8].

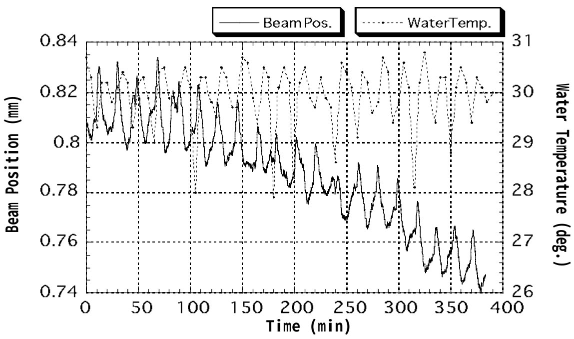

Fig. 1 Relation between beam position and water temperature.

The long period variation in Figure 1 is a result of earth tide. However, this variation mainly affects the dispersion section and is not significant in the straight sections containing insertion devices. By contrast, the effects of variations in cooling water temperature affect the whole ring and cause photon beam fluctuation.

It appeared that the C-shaped bending magnets were most susceptible to cooling water temperature variations. Consequently we measured their variations[9].

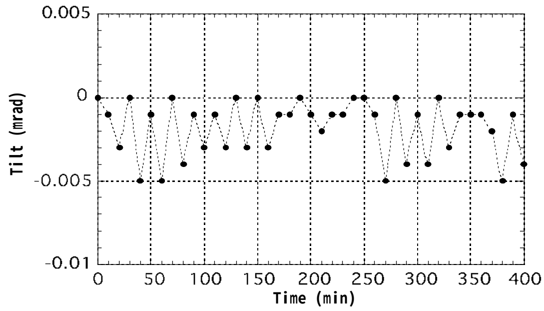

Fig. 2 Bending magnet tilt angle variations.

Figure 2 shows the results of these measurement. They indicate a clear correlation between the temperature oscillation and the bending magnet tilt variation, which changes the gap height and field strength.

Facility management group plans to stabilize the temperature variation of magnet cooling water.

Girder and Magnet Temperature Variations

The vertical beam orbit was observed to move downwards for a few days after turning on the magnet power supplies[10]. Before commissioning, we measured girder and magnet temperatures[11]. Alignment changes of magnets on a girder before and after turning on magnet power supplies were also measured. These measurements indicated that it takes a few days to reach the heat valance condition. Moreover, the temperature variation at the center of a girder is 1.1℃ higher than at each of its ends. Similarly the temperature of magnets mounted on the center of a girder is 0.8℃ higher than at each of its ends. These temperature variation cause alignment changes of 12 μm at magnet's center and 17 μm at its fiducial point. The average change in fiducial point height was measured at 12 μm.

The quadrupole magnets on the middle of a girder are defocusing magnet. This means that the electron beam is kicked downwards systematically and as a results the closed orbit moves downwards. The calculated closed orbit distortion of 80 μm agreed with the measured value. We are running power supplies continually to avoid problems caused by orbit change except log shutdown periods.

Magnet Power Supply Current Ripple

In December 1997, we observed beam fluctuation of a few Hz. As beam orbit is susceptible to current ripples in the magnet power supplies, we measured the flux variation by winding the leading wire to the return yokes. Current ripple of the sextupole magnet was observed around 1 Hz. Such ripples cause eddy currents in the asymmetric chamber that produce dipole fields inside the chamber[12]. Using the measured flux variation, we calculated the orbit variation and found that there was a possibility to vary beam orbit 50 µm at maximum. As there have not been any beam variations since last December, we do not consider that there is an immediate need to take further action. Nevertheless, we are continuing to monitor power supply current ripples closely.

Temperature Measurement of Magnets

Since temperature variation has a direct affect on beam orbit, we monitored the temperature of cooling water, power supply room, air in the tunnel, magnets and girders for a cell. We plan to increase the monitoring points and study the effect of temperature to stabilize the beam orbit.

In addition to the temperature measurement, we plan to measure the effect of vibration on beam orbit[13], especially in the vertical direction and stabilize the electron beam within 1 µm.

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