Magnets, Power Supplies and Alignment

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High quality magnets and their precise alignment play the more important role as emittance of storage ring decreases and sensitivity against errors increases. We have made high quality magnets and aligned them in the SPring-8 Storage Ring tunnel with high accuracy.

1. Magnets and Power Supplies

Integrated field strength and field distribution have been measured for 88 dipole, 480 quadrupole and 336 sextupole magnets[1]. Figure 1 shows the integrated field gradients for quadrupole magnets measured by a harmonic coil. Error fields were within the tolerances and we were confirmed that all the magnets have high quality in accordance with the design values. Magnetic centers of quadrupole and sextupole magnets were also measured by the harmonic coil and transferred to fiducial points on the magnets. These transferred points were used for magnet alignment. Field measurements of all the magnets were finished in June 1995.

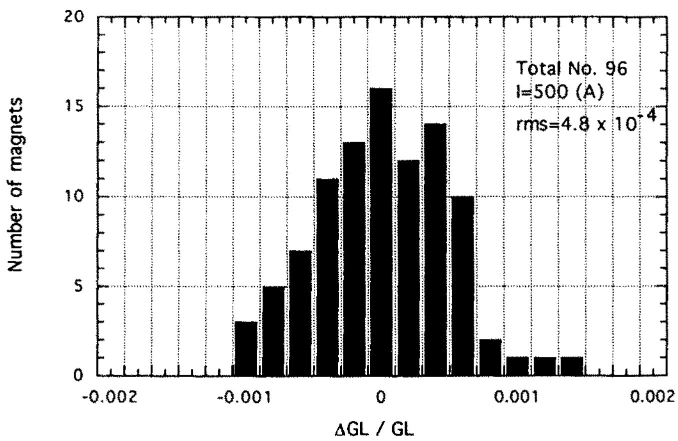

Fig. 1. Distribution of the integrated field gradients for quadrupole magnets.

Steering magnets having low remanent field were designed on the basis of test results of a prototype magnet. Fabrication is going on in a company and all the steering magnets will be delivered in September 1996.

Four bump magnets, one pulsed and three DC septum magnets, are used for beam injection. Prototype magnets were made and the characteristics were studied[2]. We obtained satisfactory results and completed the final design.

All the power supplies of dipole, quadrupole and sextupole magnets were installed in the four power supply rooms distributed along the inside of the ring. Power supply cables except steering and injection magnet cables have been laid.

Bump magnet and pulsed septum magnet power supplies were designed on the basis of prototype power supplies. They will be delivered until the end of October 1996.

Magnet power supply control system which consists of UNIX work stations , an optical fiber network and VME modules was developed[3]. The programing of power supply control started in collaboration with control group.

2. Girders and Alignment

In February 1995 the first girder was delivered and installed in the Storage Ring tunnel. Performance was tested and high quality of the girder was assured. In March the delivery of remaining 143 girders started and was completed in September.

After the performance test of the girder, magnet alignment started. The alignment tolerance is so small and the given time for the alignment is not so long that we needed rigorous study of the alignment method and procedure beforehand. After the discussion we determined to align the 904 magnets through next six steps[4].

The first step is installation of the girders and the magnets. They are carried to the tunnel by pallet tracks. The girders are set on base plates and the girder level is adjusted. The magnets are put on a girder by a crane. The second step is rough alignment of the girders and the magnets. Fiducial points at every bending section are used for positioning of the girders and the magnets. Theodolites, NA2 level and special instruments are used for the alignment of horizontal, vertical and longitudinal direction respectively. At this stage position accuracy is within 0.5 mm. The third is survey and alignment between the girders[5]. Survey is done using the laser tracker SMART 310. The fourth step is bending magnets alignment. They are carried by pallet tracks and set on girders by a crane. Alignment is done by measuring the magnet position using SMART 310. The fifth is precise alignment of the magnets on a girder. The quadrupoles and the sextupoles on a girder are aligned using the high accuracy laser system which consists of a He-Ne laser, a CCD camera and a computer. Finally the quadrupoles and the sextupoles on the girders are divided into two pieces and vacuum chambers are installed. After the installation of chamber the magnets are recovered. In these six steps, step 5 is the most important one. By aligning the magnets on a girder with high accuracy, the closed orbit distortion can be suppressed within small values even if the magnets between the girders are not aligned precisely[7][8].

Step1 and step 6 were done by a company. Step 2, 3, 4, 5 were done by 10 magnet group members. This alignment group was divided into four teams and one team took charge one step. Basically step 3 should be done for the whole ring after all the magnets are installed in the tunnel. However, to shorten the time we divided the whole ring to five areas and in each area step 3 alignment was carried out: 48 cells are divided into 4 cells, 8 cells, 8 cells, 12 cells and 16 cells and after finishing rough alignment for the first 4 cells, survey and alignment between the girders for the 4 cells has started. Alignment for remaining four areas was also done with the same way.

First step started in April 1995 and step 2, step 3 and step 4 started successively. Figure 2 shows the magnet alignment on a girder by laser system (step5). The alignments for the first 4 cells were finished in July and the chamber installation and magnet recovery were completed in August. At this stage we

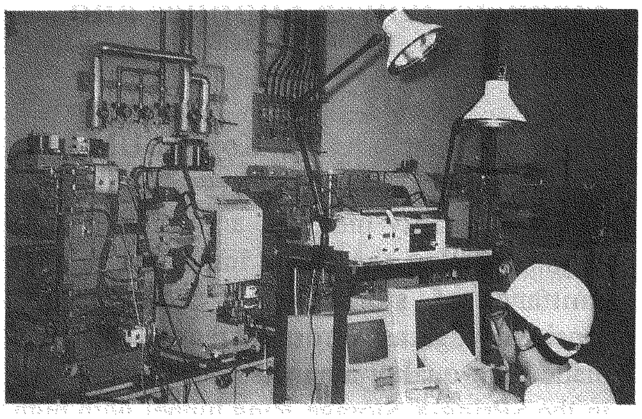

Fig. 2. Magnet alignment on a girder by laser system.

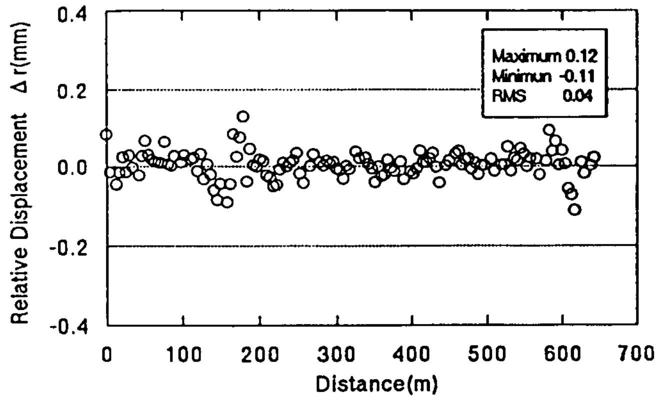

Fig. 3. Relative displacement of the magnets between the neighboring girders.

were convinced the success of magnet alignment. In March 1996 all the alignment except the steering magnets were completed. In Fig. 3 relative displacement between neighboring girders are shown.

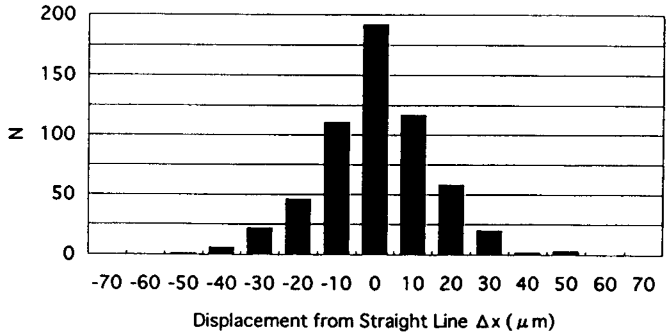

Fig. 4. Alignment results of the magnets on girders by laser system.

Standard deviation is 40 μm, which is small enough compared to the tolerance of 0.2 mm. Alignment results of the magnets on girders which were measured after chamber baking are shown in Fig. 4. Taking the trasformation error of magnetic center and measurement error into account, alignment error of step 5 is estimated to be 40 μm, which is less than the tolerance of 50 μm.

3. Vibrations

Effective emittance of the electron beam increases if magnetic center of quadrupole magnets vibrates. This effect is important for low emittance storage ring especially when we pursue a higher brilliance by decreasing the natural emittance or coupling between the horizontal and the vertical betatron ocillations. Therefore we measured the vibrations and evaluated the effects on the electron beam. Measurements were done under the various conditions for the cell which was constructed for pre-assembly test prior to the construction of whole cell. Maximum vibration amplitude was 0.01 μm for horizontal and vertical directions when the cooling water system was operated. This value is small enough and the effective emittance growth can be neglected even in the case of 1 % coupling of betatron ocillations.

References

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