LARGE ANGLE PRECISION ROTATING TABLES FOR SEXTUPOLE MAGNETS IN SuperKEKB

Ryuhei Sugahara [A), *] , Mika Masuzawa [A)], Tatsuya Moriyama [B)]

A) High Energy Accelerator Research Organization (KEK)
1-1 Oho, Tsukuba-shi, Ibaraki, 305-0801, Japan
B) Tokyo Giken, Inc.
4-42-37 Higashi Yamada, Tuzuki-ku, Yokohama-shi, Kanagawa, 224-0023, Japan

Abstract
Beams have to be tuned precisely in the collision region in order to get the beam size as small as about 50nm vertically in the SuperKEKB operation [1]. Large angle precision rotating tables have been fabricated as a tool to handle this precision beam tuning. Rotating tables rotate precisely 24 sextupole magnets in the LER beam line in the collision area from -30 to +30 degrees. The fabrication of these large angle precision rotating tables is reported.

1. INTRODUCTION
Beams have to be tuned precisely in the collision region in order to get the beam size as small as about 50nm vertically in the SuperKEKB operation [1]. Large angle precision rotating tables have been fabricated as a tool to handle this precision beam tuning. Rotating tables rotate precisely 24 sextupole magnets in the LER beam line in the collision area from -30 to +30 degrees to change the function of magnets from the sextuple to the skew-sextupole. The precision of the rotation is expected to be 0.1mrad. The rotation is controlled from the KEKB central beam operation room. The rotating tables have to be made compact as the space in the accelerator tunnel is very limited. The sextupole magnets to be rotated have been modified on the arrangement of the electric cables and the cooling water horses in order for the magnets to fit in these compact rotating tables. Figure 1 shows a sextupole magnet mounted on a rotating table and installed in the accelerator tunnel.

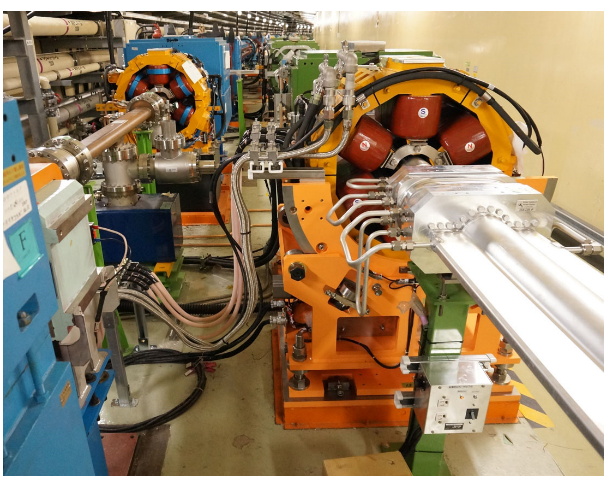

Figure 1: A rotating sextupole magnet installed in the tunnel.

* ryuhei.sugahara@kek.jp

2. THE MECHANISM
The fabrication drawing of the rotating table is shown in Figure 2(a) and (b). A helical gear is fixed at the bottom of the magnet support part, a straight worm gear is fixed on the top of the support base, and these gears are engaged. The magnet support part is rotated by rotating the straight worm gear with a pulse motor. The radius of the helical gear is 450mm. The extended view of the gear part is shown in Figure 3. The position of the magnets can be adjusted vertically and horizontally with adjusting screw bolts at the magnet mounting plates. The position of the whole system of the magnet and the rotating table can also be adjusted vertically and horizontally with adjusting screw bolts at the base plate.

3. ADJUSTMENT OF THE MAGNET CENTER TO THE ROTATION CENTER
The position of the magnet center has to be adjusted to the center of the rotation. This adjustment was carried out by observing the vertical and horizontal displacement of the hair crosses in the close plane and in the far plane as well with a theodolite telescope. The hair crosses were prepared by stretching 0.1mm thick beryllium cupper wire between the facing edges of the magnet pole pieces as shown in Figure 4. Three wires were stretched, and their

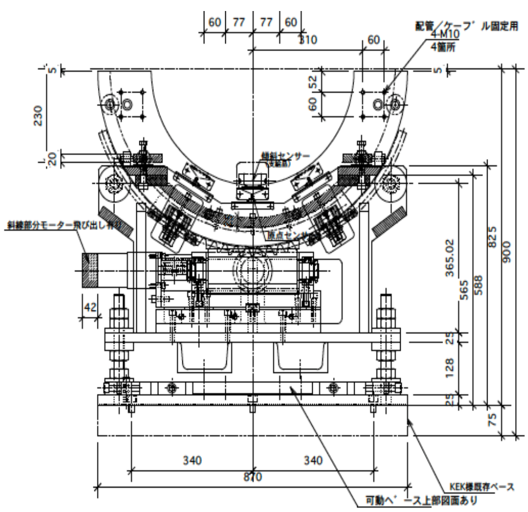

Figure 2(a): The front view of the rotating table.

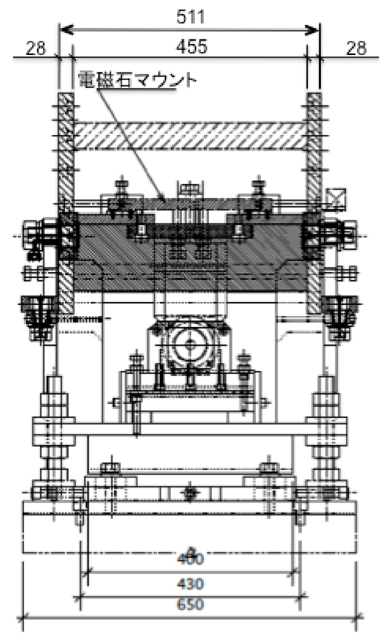

Figure 2(b): The Side view of the rotating table.

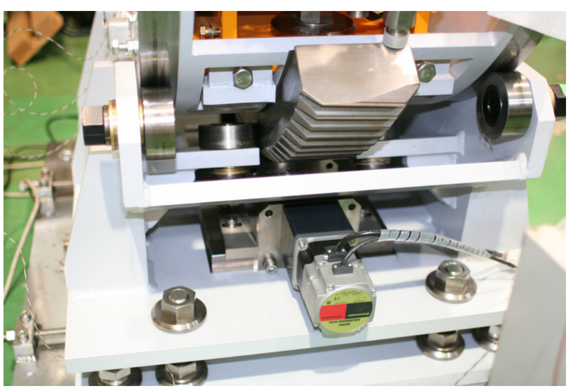

Figure 3: The picture of the gear system.

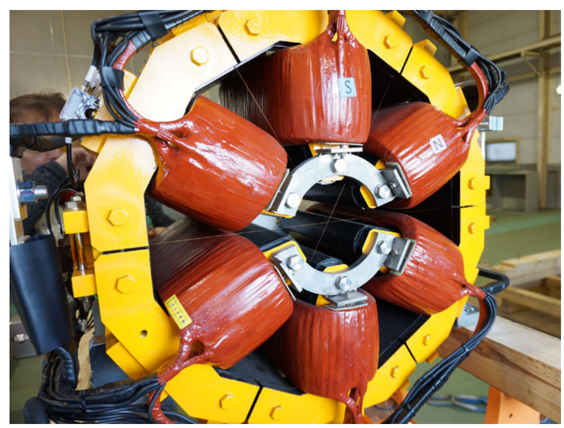

Figure 4: Hair crosses stretched between facing boundaries of pole pieces.

crossing point was referred as the center of the magnet. Hair crosses were prepared in both sides of magnets.

First of all, a rotating magnet system is adjusted level by watching a digital bubble level placed on the alignment base on the back of the magnet. Then the theodolite telescope is adjusted so that its optical axis is placed along the line connecting the close and far hair crosses. Then the magnet is rotated 30 degrees, and the vertical and horizontal displacements of the close and far hair crosses are measured. Next the magnet is rotated -30 degrees, and the displacements are measured. From these measurements, the displacement of the magnet center is calculated as follows:

$$dX = (Y_{+} - Y_{-}) / (2*\sin(K))$$
$$dY = -(X_{+} - X_{-}) / (2*\sin(K))$$

where the origin of the coordinate system is arbitrary, and X and Y are the horizontal and vertical axis correspondingly. The position (X_{+}, Y_{+}) is that for the hair cross when the magnet is rotated +K degrees, and (X_{-}, Y_{-}) when the magnet is rotated -K degrees. dX and dY are the displacements of the magnet center from the rotation

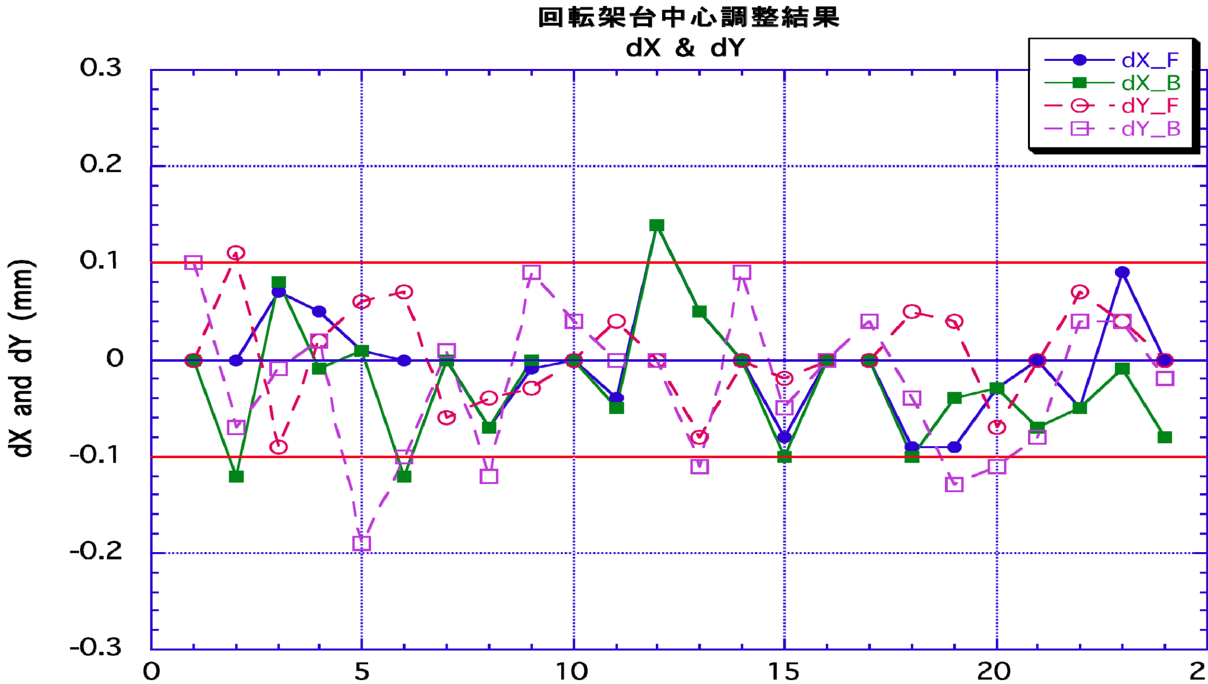

Figure 5: Displacements of the magnet center from the rotation center after the adjustment, where dX and dY present displacement in X and Y directions respectively. The suffixes F and B show those in the close and far plane.

center. These displacements are measured and corrected with the adjusting screw bolts at the magnet mount for the close and far hair crosses. This process is repeated until all the displacements become smaller than 0.1mm. Adjustment results are shown in Figure 5, where the final values for the displacements are shown for 24 rotating sextupole magnets.

4. THE CONTROL SYSTEM AND THE OPERATION

Sextupole magnets are placed on X-Y movers in the KEKB project [2]. These X-Y movers were controlled from the central KEKB beam operation room through 8 local control huts, LC1 to LC8, and the control room in the D2 electric power building at Tsukuba area. The X-Y movers for 24 sextupole magnets in the LER line in the Tsukuba area were replaced by the precision rotating tables. Control cables connecting the X-Y movers in the tunnel and the surface local control huts are re-used for the rotating tables. Ten rotating tables in the left area, looking from the accelerator ring center, are connected to the LC8 local control hut, right ten rotating tables to the LC1, and the central four rotating tables to the control room in the D2 electric power building. Control electronics such as pulse motor drives and control PLC modules are installed in the LC8 hut, the LC1 hut and the D2 building. PLC modules of Keyence control directly the rotating tables, which receive commands from and transfer status signals to the KEKB central beam operation room through Yokogawa PLC modules placed in the local control huts and the D2 building.

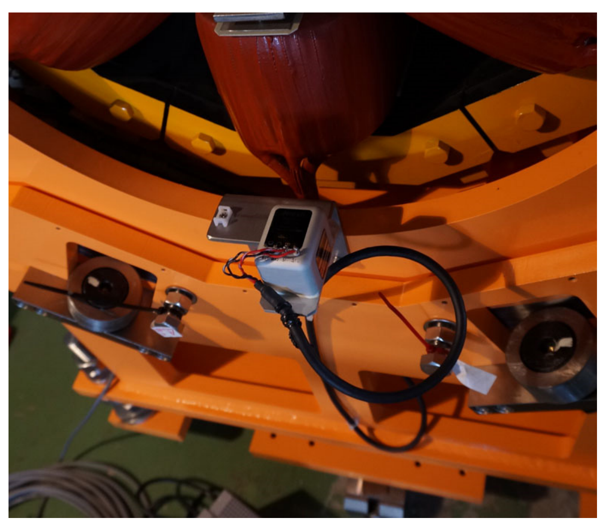

Figure 6: The tilting sensor installed to the rotating table.

Tilting sensors LCI-30 of Jewell Instruments are installed to each rotating table as shown in Figure 6. These sensors can measure the tilt from 0 to 90 degrees. Outputs from these sensors are fed to ADC modules in the

Yokogawa PLC module systems. These outputs from the ADC modules have to be read by the central control system after some rotation is executed. If the value is not within the tolerance of 0.1 mrad, tables have to be rotated again reversely by the amount of the error. The backlash of the rotation can be cured with this process. Aiming rotation angle can usually be achieved in two or three trials.

5. INSTALLATION

The rotating sextupole magnets were installed in the tunnel after the adjustment of the magnet center to the rotation center. Holding jigs were fabricated to hold and lift the whole system of the rotating sextupole magnet as the magnet and the rotating table could not be separated after the adjustment of the magnet center. These holding jigs had to be strong enough to lift the weight of 700kg of the magnet plus 700kg of the rotating table. These rotating sextupole magnet systems were aligned to the beam line and adjusted level by observing a bubble level placed on the alignment base on the back of the magnet. Fig.1 shows a rotating sextupole magnet installed in the tunnel.

SUMMARY

Large angle precision rotating tables have been fabricated as a tool to achieve the precision beam tuning in the SuperKEKB operation. Rotating tables rotate precisely 24 sextupole magnets in the LER beam line in the collision area from -30 to +30 degrees at the precision 0.1mrad. Sextupole magnets to be rotated have been modified on the arrangement of the electric cables and the cooling water horses in order to fit in the rotating tables. The magnet center was adjusted to the rotation center at the precision 0.1mrad before the magnets were installed in the accelerator tunnel. The rotation is controlled from the central KEKB beam operation room through the local control hut LC1 and LC8 and the control room in the D2 electric power building. The tilt angles of magnets are measured with tilting sensors LCI-30 of Jewell Instruments. Signals are fed to ADC modules placed in the local control huts and the D2 building, and their outputs are read by the central beam control system. If the value is not within the tolerance of 0.1 mrad after the rotation, tables have to be rotated again reversely by the amount of the error. The backlash of the rotation is cured with this process. Aiming rotation angle can usually be achieved in two or three trials.

The authors would like to thank the people of Tokyo Giken, Inc. for their effort in the fabrication of the rotating tables. They also appreciate the cooperation of the people of the control group of KEKB in the construction of the control system for the rotating sextupole magnets.

REFERENCES

[1] Y. Ohnishi et al., Prog. Theor. Exp. Phys. 2013, 03A011.
[2] KEKB B-factory Design Report 95-7, June, 1995.