DEVELOPMENT OF ACTIVE TABLES FOR LINEAR COLLIDERS

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Abstract

Active supporting tables were designed and made to control the position of the ATF damping ring. Their performance has been investigated. The results of positioning test show that they have enough performance within required accuracy for the positioning of the ATF damping ring magnets. The outline of these active tables and the results of the test are presented. The application of these active tables to the main linac of linear colliders which has requested the positioning resolution of 10 μm is discussed.

1. Introduction

The Accelerator Test Facility (ATF) in KEK contains a damping ring. For obtaining a very low emittance beam, magnets of the ring have to be aligned within 30 μm. The relative movement of magnets due to the ground motion is, however, shown to be the same order as the tolerance above[1]. Therefore we must correct the relative movement between magnets automatically. For this purpose, we install a set of magnets on an active support table and the position of the table is controlled to maintain relative alignment between tables. We also mount each wiggler magnet on an active support to control its position and orientation.

In this paper, we describe the designs of the support table and wiggler support and their performance of positioning. The application of the present design to the active table for main linacs of linear colliders is also discussed.

Fig. 1 Active support tables for the arc section

2. Design of the Tables

2-1. Tables for the arc section

Figure 1 shows the tables for the arc section. The table consists of a base plate, three movers, a surface plate, and joints between the movers and the surface plate. A set of magnets, i.e. one bending magnet, two quadrupole magnets, and two sextupole magnets, are mounted on each table. The alignment of the magnets on the table are carried out in an alignment hut in the ring tunnel. Then the table with magnets is moved and installed in the beam line.

Base Plate The base plate is an iron plate with the thickness of 30 mm. This thickness was chosen so that the magnet alignment is not disturbed due to the distortion of the base plate during the movement from the alignment hut to the beam line.

Mover Three movers are bolted on the base plate. One of them has three stages: the lowest stage moves in beam direction (in z-direction), the middle one horizontally and perpendicularly to the beam (in x-direction), and the highest one vertically (in y-direction). The other two have only two stages, each: x-stage and y-stage. Each stage moves along linear rail guides. The z-stage is manually driven, while the x- and y-stages are moved by ball screws driven by pulse motors. The range of the movement is ±20 mm.

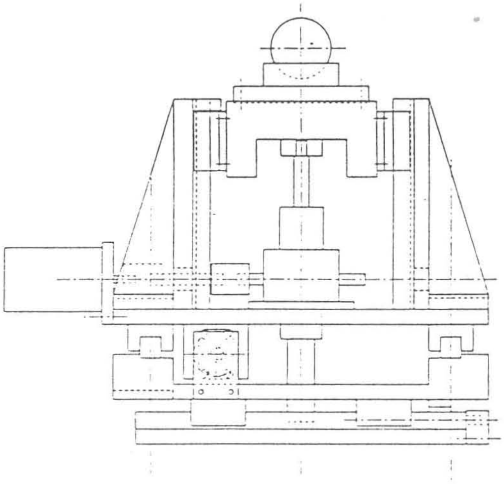

Fig. 2 Assembly drawing of the mover

Surface Plate The surface plate has a non-magnetic top plate and iron bottom plate. Non-shrink mortar is filled between the plates. We made three types of surface plates on trial: one has an aluminum upper plate, another a stainless one, and the other the mortar surface where several small plates of stainless steel are attached to mount and bolt the magnets. Comparing these three, we have chosen the stainless upper plate because it is convenient to the alignment work and hard to be scratched. The thicknesses of the upper and bottom plates are 20 mm and 15 mm, respectively. The surface plate has the total thickness of 170 mm and the weight of about 1 t.

Joints between the Movers and the Surface Plate Joints are inserted between the movers and the surface plate to make the table movement smooth. Each joint consists of a ball bearing and a cradle. The ball bearing is for conveying heavy goods and made up of a large ball to hold weight and small balls to make the rotation of the large ball smooth. It is fixed on the top of the mover and the cradle is attached to the bottom surface of the surface plate.

To make the mover design simple and reduce the cost, we use three types of the cradles. The cradle for the mover A (see Fig. 4) has a conical hollow which the ball fits in. Therefore, this joint has degrees of freedom for the rotation around the center of the ball, but no degrees of freedom for the movement in the x-z plane. The cradle for the mover B has V-shaped groove where the ball fits. The surface plate can move freely along the direction of the groove (z-direction), but is constrained in the transverse direction (x-direction). The cradle for the mover C is a flat plate so that the surface plate slide in any directions.

2-2. Support for the Wiggler Magnet

What is important about the wiggler magnet is to maintain it horizontal. For this purpose, each wiggler magnet is installed on a support which consists of a base plate and three movers. The mover has the y-stage only whose design is basically the same as that of the mover for the arc section. We use ball joints between the movers and the wiggler magnet for the smooth movement. With this support, we can control the vertical position, roll (rotation around the z-axis), and pitch (rotation around the x-axis) of the wiggler magnet. We gave up the control of yaw (rotation around the Y-axis) because small effects due to the misalignment of the yaw can be corrected by horizontal steering and quadrupole magnets.

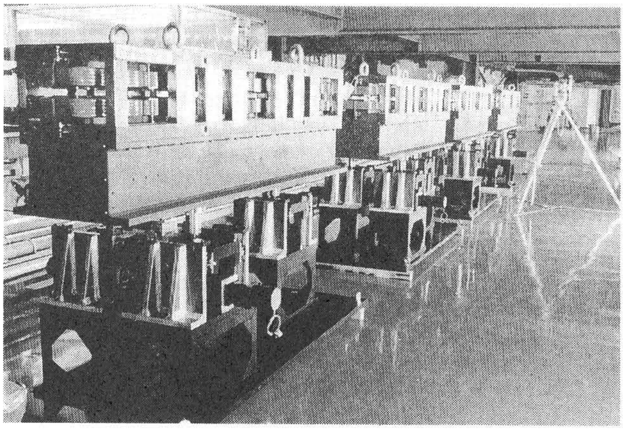

Fig. 3 Support for the wiggler magnet

3. Safety for the Earthquake

Accelerator components must be earthquake-proof. The wiggler magnet on its support is top-heavy and seems to be rather weak against the earthquake. Therefore we have carried out a shaking test and made sure the safety[2].

4. Test of the Positioning Resolution

4-1. Table for the arc section

Tests were carried out with a dummy weight of 865 kg on the table instead of the magnets. Vertical displacements were measured at points a, b, c, and d in Fig. 4 with the accuracy of 2 μm.

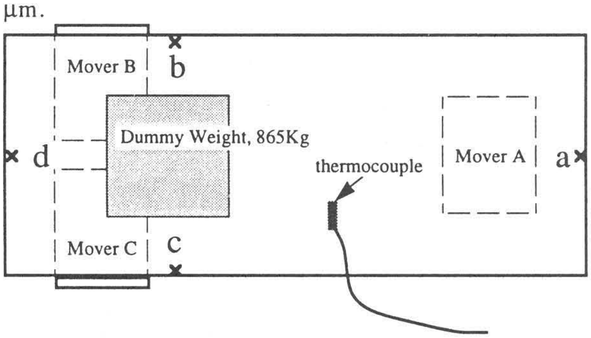

Fig. 4 Position of the measurement

First, the vertical positioning was tested. The surface plate was raised and then lowered by about 1.3 mm, and this up-and-down cycle was repeated once more. The results show a good linearity, but it moves on different trajectories when it is raised and lowered, as shown in Fig. 5. Although two trajectories are apart from each other about 5 μm, the reproducibility of each trajectory is very good. We consider that this phenomenon is due to backlash of the ball screw of the y-stage. In order to estimate the performance of the table, we chose one trajectory and made a linear fit. The deviation from the fitted line is shown in Fig. 6. The vertical position of the table can be controlled within the accuracy of better than 2 μm.

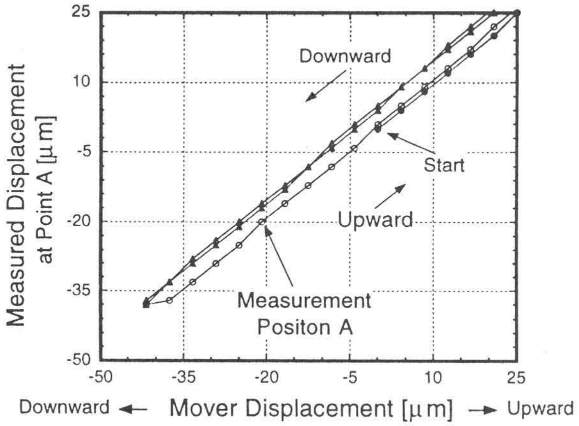

Fig. 5 Result of the test : vertical movement

The tests of the roll and the pitch were carried out as well. The results also show double trajectories due to the backlash. Linear fit was done with the data on each single trajectory. Deviations from the fitted lines are shown in Fig. 7 and Fig. 8 for the pitch and roll, respectively. The pitch angle can be controlled within 2.5 μrad, while the error of roll angle becomes about 10 μrad.

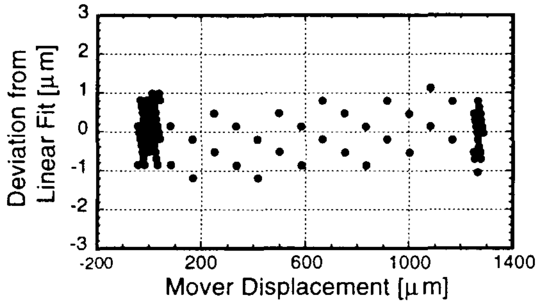

Fig. 6 Deviation from the fitted line : vertical movement

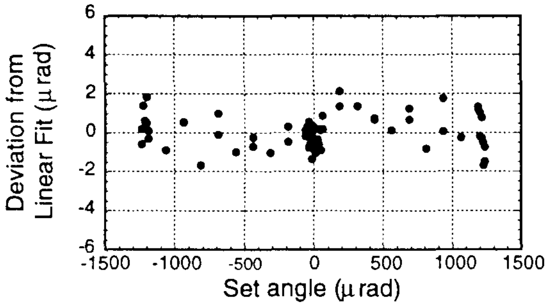

Fig. 7 Deviation from the fitted line : pitch

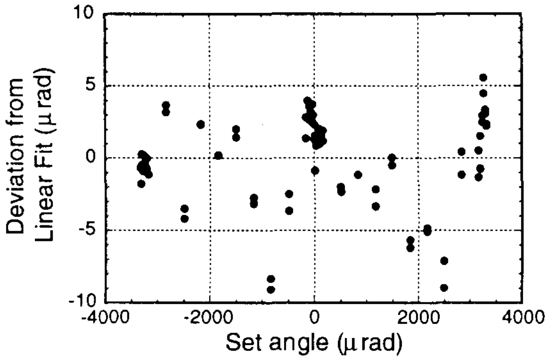

Fig. 8 Deviation from the fitted line : roll

We suppose the reason of this difference between the pitch and roll is that the joint having the cradle with the V-shaped groove does not function well for the rotation around the axis parallel to the direction of the groove.

As for this problem, a new joint which consists of a ball joint and a linear rail guide has been developed. Preliminary results show it works well. We expect the deviation of the roll will be reduced with the new joints to the same level as of the pitch.

4-2. Support of the wiggler magnets

The wiggler magnet was mounted on the support and moved up-and-down twice. The range of the movement was about 1.3 mm. The results show the same features as those of the support table: the good linearity and the double trajectory due to the backlash. The fit to one trajectory shows that the vertical position can be controlled within 3 μm, as shown in Fig. 9.

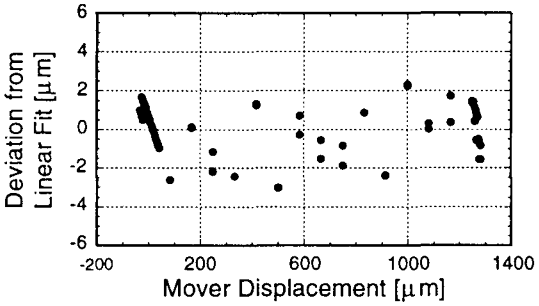

Fig. 9 Deviation from the fitted line : vertical movement (wiggler support)

5. Summary

We have developed the active support table for the magnets of the arc section of the ATF damping ring. Also developed is the support for the wiggler magnet. The support table and the wiggler support show the precision better than 2 μm and 3 μm, respectively, for the control of the vertical position. The pitch and roll of the table can be controlled within 2.5 μrad and 10 μrad, respectively. Both of them satisfy the positioning resolution required for the ATF damping ring.

The required tolerance for the alignment of the accelerating structures of main linac of linear colliders is about 10 μm. Therefore, active tables whose resolution is better than 10 μm are necessary. We consider that tables with the present movers satisfy this requirement sufficiently.

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References

[1] S. Takeda et al., "Slow Ground Motion and Alignment System", contribution to the 4th European Particle Accelerator Conference (EPAC94), London, U.K., June 27 - July 1, 1994; KEK Preprint 94-48, June 1994

[2] T. Suzuki et al., to be submitted.