

# THE MAGNET ALIGNMENT OF THE KEK-PS MAIN RING

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## Abstract

It is about 25 years since the construction of the KEK-PS 12 GeV main ring. The peak beam intensity has been achieved up to  $8.0 \times 10^{12}$  ppp at the top energy and the KEK-PS main ring is continuously providing the high intensity proton beam of over  $6.5 \times 10^{12}$  ppp in every 2.2 seconds for the neutrino experiments. But sometimes there are some difficulties in order to keep or resume the beam intensity to over  $7.0 \times 10^{12}$  ppp.

Generally, it is possible to construct the ring to have less than 10 mm of closed orbit distortion without any orbit handling system. However at the KEK-PS main ring, the COD becomes more than 20 mm. This large ‘bare’ closed orbit distortion strongly suggests the abnormally bad magnet misalignment. In summer of 2000, the horizontal magnet positions were measured for the first time since the construction. Then it was proved that the ring was distorted about the magnitude of 10 mm at the maximum.

In this paper, the overview and the present status of the magnet alignment of the KEK-PS main ring are presented. The most important reason of the ring distortion is considered to be a ground motion. The long range ground motion and its effect onto the beam orbit are also discussed.

## 1 INTRODUCTION

In summer of 1996, the vertical alignment of 48 bending magnets and 56 quadrupole magnets was carried out in order to suppress the vertical deviation within  $\pm 1$  mm with respect to the booster extraction line. The height of 10 magnets at the injection porch of the main ring are flatten.

In summer of 2000, the three dimensional magnet position measurement was carried out for all main magnet components: 56 quadrupoles and 48 bendings. It was the first measurement for the horizontal position since the construction of the main ring in 1974. Because the horizontal distortion was found to be much larger than the expected amount, the horizontal re-alignment was given up from the point of view of radiation control and geometrical characteristics of some components. On the other hand, the vertical re-alignment was completed achieving the small vertical displacements within  $\pm 0.5$  mm.

In summer of 2001, the 3D measurement of magnet position was carried out again only for quadrupoles in order to investigate the 3D ground motion with respect to time.

The accelerator tunnel is not so stable. A periodical position measurement and re-alignment is important in order to keep the machine performance because the accelerator and its tunnel will be distorted by the forces from the soil and ground water[1][2][3]. The floor of the KEK-PS main ring consists of eight part of plates from A1 to D2 as shown

in Fig.1, and the plates are not symmetric each other. The junction of plates is called as an expansion joint. The tunnel distortion can be explained by the plate movements, and expansion joints play an important role on the ground motion dynamism.

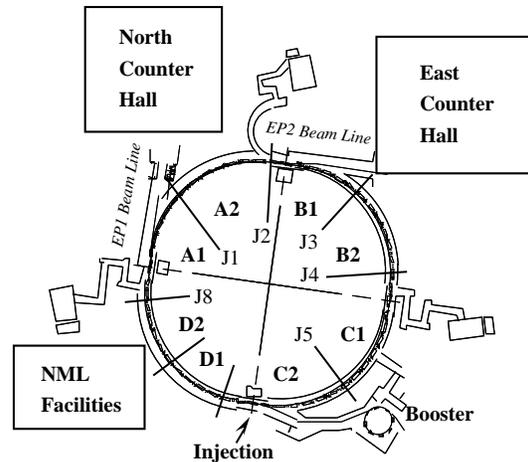


Figure 1: Layout of floor plates. The KEK-PS has 56 quadrupole magnets. The floor is divided into 8 parts of plates from A1 to D2, and J1 through J8 are expansion joints. The first quadrupole (I-1F) is located on the plate C2 at just before the injection point.

## 2 ALIGNMENT DISTORTIONS

### 2.1 Vertical Motion

A water cup is attached on the outer side of each quadrupole magnets and all the cups are joined by a hose each other. The vertical positions of quadrupoles can be detected by measuring the water levels with micrometers. Though this is a fast and easy method, it only tells the time-relative vertical displacement for each quadrupoles. For the magnet re-alignment, an absolute position measurement is necessary by using more accurate equipments.

Every year, the vertical position of quadrupole magnets has been monitored by the water level measurement. Figure 2 shows the level of quadrupoles in 1990 and 1996 before re-alignment. A big distortion is observed from the quadrupole number 15 (II-1F) to 38 (III-5D) in 1990. There is the NML (Neutron and Meson Laboratory) experimental facilities (which were called as ‘BSF’ before 1997) on that direction, and the ground seems to be descending because of the weight of radiation shields, target stations, other detectors, and so on. This descent was corrected within  $\pm 0.5$  mm by ascending the magnets in summer of 1991.

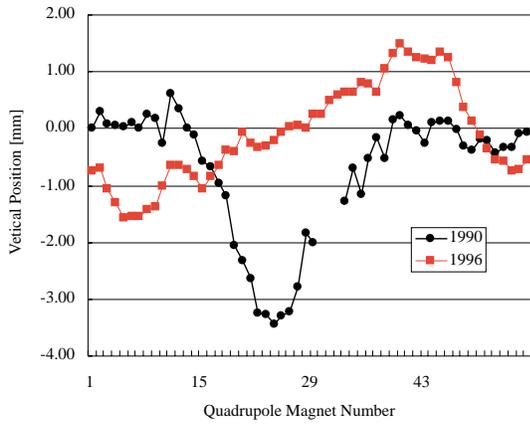


Figure 2: Vertical displacements of the quadrupole magnets before re-alignment. The magnet number 1 corresponds to I-1F. The measurement of 1996 was done by a theodolite.

The characteristics of the ground motion apparently changed after the construction of North Counter Hall in 1990, from the descent to the rotation. The main ring tunnel has been inclining in one direction around a line connecting the expansion joints J1 and J5. The plate D2 is descending, on the other hand, the plates B1 and B2 are ascending about 300 micrometers per year. The ground motion is being monitored by other methods, observing not only the slow ground motion but also the fast (time scale of several days) ground motion[4]. All the results support the ground motion observed in the magnet re-alignment process of 1996.

## 2.2 Horizontal Motion

The laser tracker SMX-4500 was used for the accurate position measurement in 2000. The accuracy of SMX-4500 is  $\pm 1.1$  micrometers. As the each of quadrupole magnets has two target points along the beam line, the rotation around the vertical axis also can be detected. Twenty six monuments were newly set up as the base points for accurate measurements because the laser tracker is not so good at measuring the linear-lined objects. The magnets are placed along the beam line almost linearly, and these monuments provide the third point away from the beam line. And they also provide a direct evidence of horizontal ground motion.

The horizontal distortion of the main ring magnets measured in summer of 2000 is shown in Fig.3. One can see that the main ring tunnel is pushed from the two directions: one comes from the NML facilities and the other comes from the East Counter Hall which are shown in Fig.1. The amount of horizontal distortion is more the 9 mm at the maximum. If this squeezing began in 1990 when the North Counter Hall was constructed, the speed of horizontal movement of floor plates is about 1 mm per year. It is considered to be the origin of the horizontal large bare COD observed at the KEK-PS main ring. The horizontal COD without steering correction is more than 20 mm.

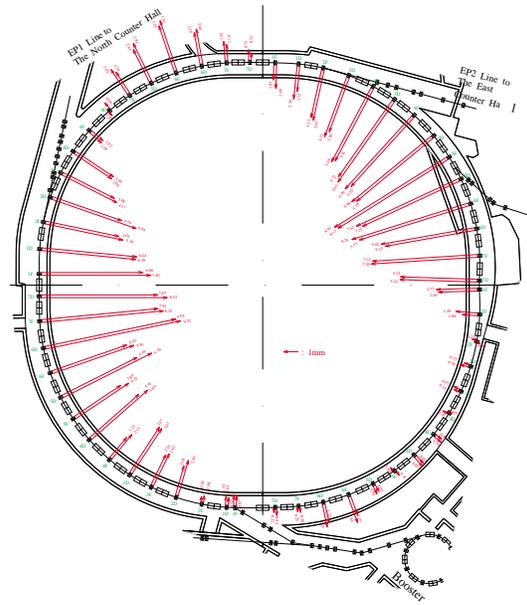


Figure 3: Horizontal displacements of the quadrupole magnets in radial direction measured in 2000. The lengths of arrows indicate the amounts of deviations. The largest deviation is more than 9 mm. The KEK-PS main ring is being squeezed from the 2 and 8 o'clock directions.

Moreover, Fig.4 shows the deviations in radial and vertical directions. It tells the relationship between the deviations, that is, the origin of them is common. The long time range ground motion of the main ring tunnel is caused by the weights of two experimental halls, and these two forces are continuously squeezing and rotating the main ring. According to the result of measurement in summer of 2001, the KEK-PS main ring is still rotating and squeezed with the same speeds.

Figure 5 shows the longitudinal displacements. This result also supports the plate tectonics. The distances between magnets get closer around the squeezing forces and get wider in the other areas.

## 3 CONCLUSION

Two types of ground motion are observed at the KEK-PS. The motion described in this paper is the slow ground motion. The KEK-PS main ring is continuously being squeezed and rotated around the line connecting the expansion joint J1 and J5. The origin of this motion might be the weights of the NML facilities and the East Counter Hall. The rotating speed is about  $\pm 300$  micrometers per year. This is not a negligible value. Generally, the vertical aperture is strongly restricted by the gap height of bending magnets. The vertical alignment distortion makes the vertical aperture get smaller. The periodical position monitoring and re-alignment of magnets are very important for large accelerators, especially when they are required very high performance. The higher energy and intensity are always

## 4 REFERENCES

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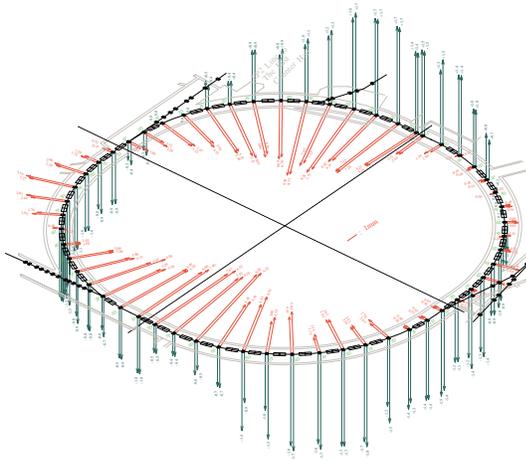


Figure 4: Bird view of the correlation between the radial and the vertical displacements of the quadrupole magnets measured in 2000. The vertical displacements are about  $\pm 2$  mm before the re-alignment. The deviations in these two directions are obviously co-related.

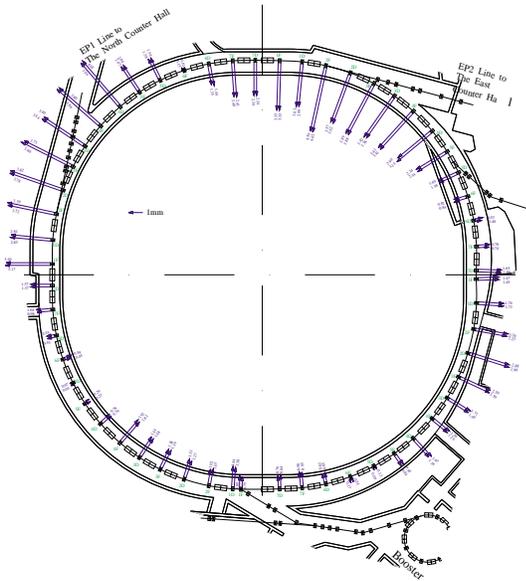


Figure 5: Longitudinal displacements of the quadrupole magnets along the beam line, measured in 2000. The deviations toward the downstream are shown by incoming arrows and those toward the upstream are shown by outgoing arrows, and the lengths of them indicate the amounts of deviations. The largest deviation is 4.6 mm. The distances between magnets are getting closer around the squeezing forces from the directions of 2 and 8 o'clock.

required, and the coming accelerators tend to have larger sizes. It is very important to consider about the stability of the constructions in a long year range for the present and future accelerators.