LONG TERM GROUND MOVEMENT OF TRISTAN SYNCHROTRON

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The long term ground movement is estimated through the geological survey before a big accelerator is planned. For the case of TRISTAN-MR (main ring), its site was surveyed to reflect the underground information to the building prior to the construction. The movement of the synchrotron magnet mainly results from the structure of the tunnel. If an individual movement of the magnet exceeds a certain threshold limit, it gives a significant effect on the particle behavior in a synchrotron. Height of the quadrupole magnets were observed periodically during past two years at the TRISTAN-MR and their height differences along the 3 km circumference of the accelerator ring were decomposed into the Fourier components depicting the causes of the movements. Results shows the movement of the tunnel foundation which was also observed by the simultaneous measurement of both magnets and fiducial marks on the tunnel wall. The long term movement of the magnets is summarized with the geological survey prior to construction.

Tunnel foundation

The tunnel of the TRISTAN-MR has been made about 12m underground. and is composed of four long experimental straight sections, each having 194m in length, expanding both sides of the colliding experimental halls, and four arc sections. It has 62 expansion joints at 50 - 60 m intervals to avoid the cracks due to the shrinkage when concrete dries. Another advantage of this structure is that it receives less effects of the ground structure under the tunnel and unbalanced weight on the tunnel. From the underground survey, the arc sections had a layer with large N-value more than 40 from 10 to 20 m underground. Thus the floor of the tunnel was determined at the level of 11 m from the ground surface and placed on that layer directly. As the floor of the experimental halls sits on the layer with low N-value less than 15, deeper than the other part of the tunnel, and tolerable ground movement for the big detectors is very small, they are supported with concrete pillars. There are buffer zones between every experimental hall and arc section gradually decreasing the pillar frequency from the experimental hall to the arc section. There are 8 buffer zones and each has 70 m length. Adopting the above supporting method, the floor level of the tunnel will be maintained in a small variation which results in a good performance of the accelerator for a long period. The layout of TRISTAN synchrotron and underground N-value variation are shown in Fig.1 and Fig.2, respectively.

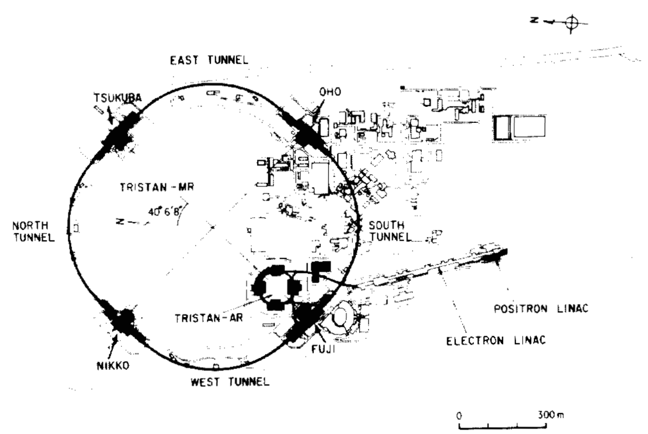

Fig.1 Layout of TRISTAN synchrotron.

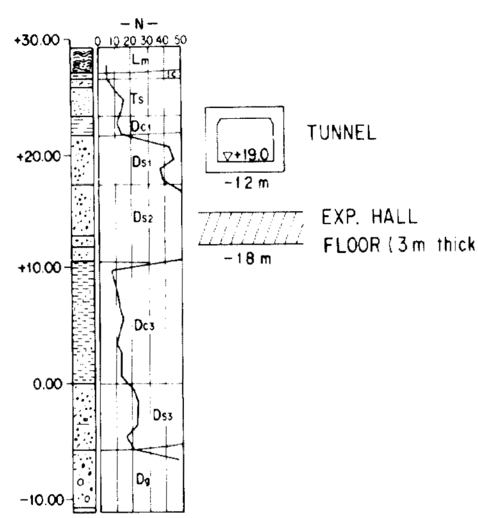

Fig.2 Typical underground N-value variation of the KEK site.
Lm= Loam, Ts and Tc= Tuffaceous clay,
Ds= Sandy soil, Dc= Cohesive soil, Dg= Gravel.

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Level variation of quadrupole magnets

During past two years, the level variations of quadrupole magnets were observed through out the MR ring and their level movements from the fiducial points were also measured to obtain the relative height variation. There is a close correlation between the levels of quadrupole magnets and those of fiducial points as shown in Fig.3. The fiducial points were marked on the tunnel wall near every quadrupole magnet three years ago, just before the installation of magnets, and re-adjusted to be at the same level every time when the global survey of the MR magnets was carried on.

Absolute level variation cannot be measured because we have no standard monitoring point to be compared. Therefore, data of this manuscript are are all relative ones. Level variation is a few mm every time and the same place of the tunnel, especially at the east tunnel, repeats the rise and sink in a year. It is not clear that it reflects the seasonal variation of the underground condition due to the weather. In general, as the clay layer swells absorbing water, the level of the clay-rich ground rises in a rainy season and sinks in a dry season. However, the dry and wet seasons does not always alternate definitely every year in Japan. Therefore the survey of the magnet levels for long time gives the answer.

If the level of the tunnel changes, it will have low order harmonics since the structure of the ground layer does not change greatly in a small area. Expanding the observed level data in Fourier series, it will become clear whether the harmful harmonics near the betatron frequency is large or not. If the harmful components become big, the fine adjustment of the magnet levels is required. The most probable harmful case is the vertical tunnel deformations due to its structure with expansion joints and with no pillar foundations. Fortunately so far, there is little evidence for this case. It is obvious from the last four measurements of levels given in Table 1.

Table 1 Harmonic analysis of four measurements of quadrupole magnet levels (unit: mm).

Reduced harmonics	Oct.1986	May,1987	Jan. 1988	Aug.1988
0-th only	0.51	0.51	0.92	0.98
0 - 19-th	0.16	0.20	0.19	0.23
0-th component	-	-3.92	3.51	1.92

The residual rms values are shown in the table after reducing the harmonics prescribed. Values

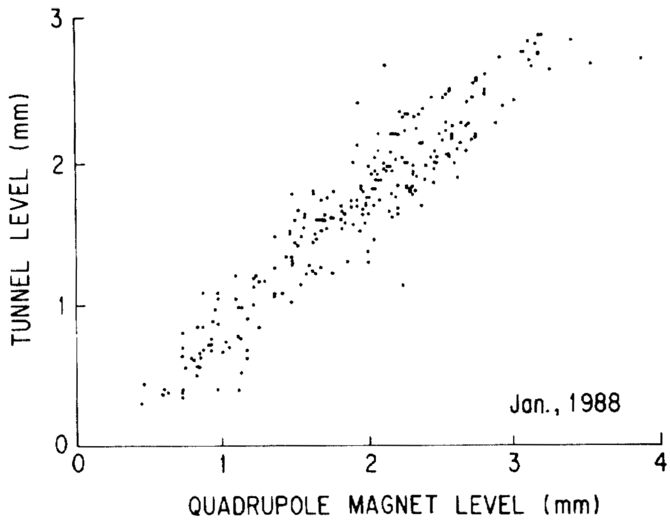

Fig.3 Correlation of levels between quadrupole magnets and fiducial points (measured at Jan. 1988).

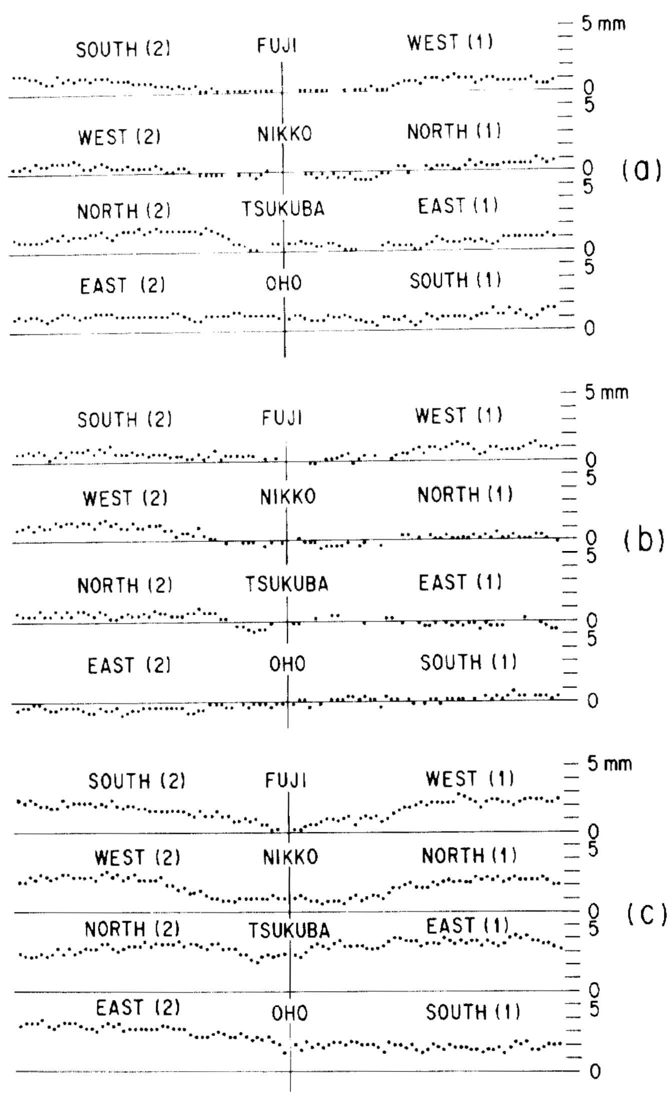

Fig.4 Relative level variations of the MR quadrupole magnets, (a) Oct. 1986 (b) May, 1987 (c) Jan. 1988.

appearing in the second row include the harmful components. A gradual increase has been observed, but it is not obstructive to the machine operation at present. The 0-th component means the average ground level variation relative to that of Oct., 1986.

Long term variation of the relative levels of quadrupole magnets are given in Fig.4 for successive three surveys. Origin of the levels is set at the Fuji experimental hall where the VENUS detector is placed. The results of the harmonic analysis are given in Table 1. There are two kinds of structures in the level variation along the MR circumference. The fine structure is due to the alignment error at the stage of initial precise alignment at installation. But the structure with long wave length is due to the ground movements.

Distributions of magnitudes of level change are given in Fig.5 for both quadrupole magnets and tunnel floor. Horizontal scale does not mean the absolute value, but it is shown for reference.

Subtracting the initial levels of quadrupole magnets measured at Oct., 1986 from the same data of Fig.4 and the latest data, the relative ground movements can be visualized as in Fig.6 adopting the first through fifth order harmonics. Circles give the level with no ground movement. The outward and inward deviations from the circle mean the upward and downward movements of the ground, respectively. Every diagram is drawn in the same scale and the maximum deviation is -1.6 mm in Fig.6(c). Through the level measurements of the MR quadrupole magnets installed in the large area for two years, the ground movements with low order harmonics occur in a short time and their amplitudes are as large as 1 - 2 mm through a year, but their phases differ every time. An equal ground movement is given by the zero-th order harmonic in Table 1. The harmful components will accumulate gradually but it takes long time until they will become large.

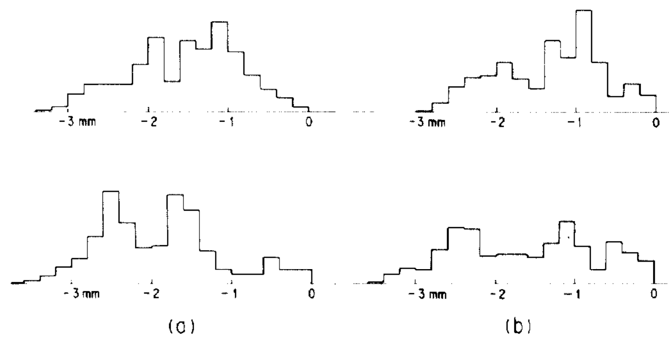

Fig.5 Distributions of magnitudes of level change for (a) quadrupole magnets and (b) tunnel floor. Upper: May, 1987, Lower: Jan., 1988. Horizontal scale is only for reference.

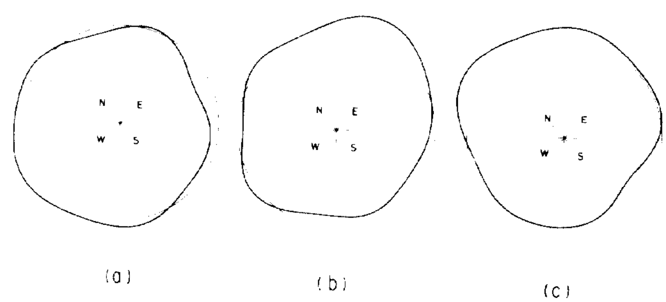

Fig.6 Ground movements relative to the initial level at Oct., 1986. (a) May, 1987 (b) Jan. 1988 (c) Aug. 1988.

Reference

[1] A.Kabe, K.Egawa, K.Takayama and K.Endo, "Precise Alignment of Magnets in the TRISTAN Main Ring," Proc. of 1987 IEEE Particle Accelerator Conference, Washington,D.C., p.1648-50.