MEASUREMENT OF THE SEISMIC MOTION AND THE DISPLACEMENT OF THE FLOOR IN THE TRISTAN RING

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1. INTRODUCTION

The design value for the beam size at the KEK B-factory is:

σ_X = 140 μm and σ_Y = 1.4 μm [1],

Hereafter the coordinate system is defined as: X is the horizontal axis and Y the vertical axis in the plane perpendicular to the beam axis, and Z is along the beam axis. The beam collision is sensitive to the displacement of magnets located around the interaction point. For example, if the final quadrupole magnet moves vertically by 0.1 mm or more, the luminosity will drop noticeably. TRISTAN ring, electron-positron collider with diameter of 1 km, is planned to be modified as a B-factory.

The seismic motion and the displacement of the floor at TRISTAN ring were measured. Measurement was carried out in Fuji and Tsukuba interaction regions. At TRISTAN ring are located four experimental halls; two are big halls and other two are relatively small. Fuji and Tsukuba experimental halls are big ones having almost the same structure and located diagonally each other. In the B-factory project, the collision point is to be placed in Fuji experimental hall at present. The plan view of the experimental hall is shown in Fig.1. The floor in the experimental hall is 16.5 m deep and that in the accelerator straight section is 12.1 m deep from the ground surface. In the experimental hall, magnets are fixed on the movable base whose top surface is 5.7 m high above the concrete floor.

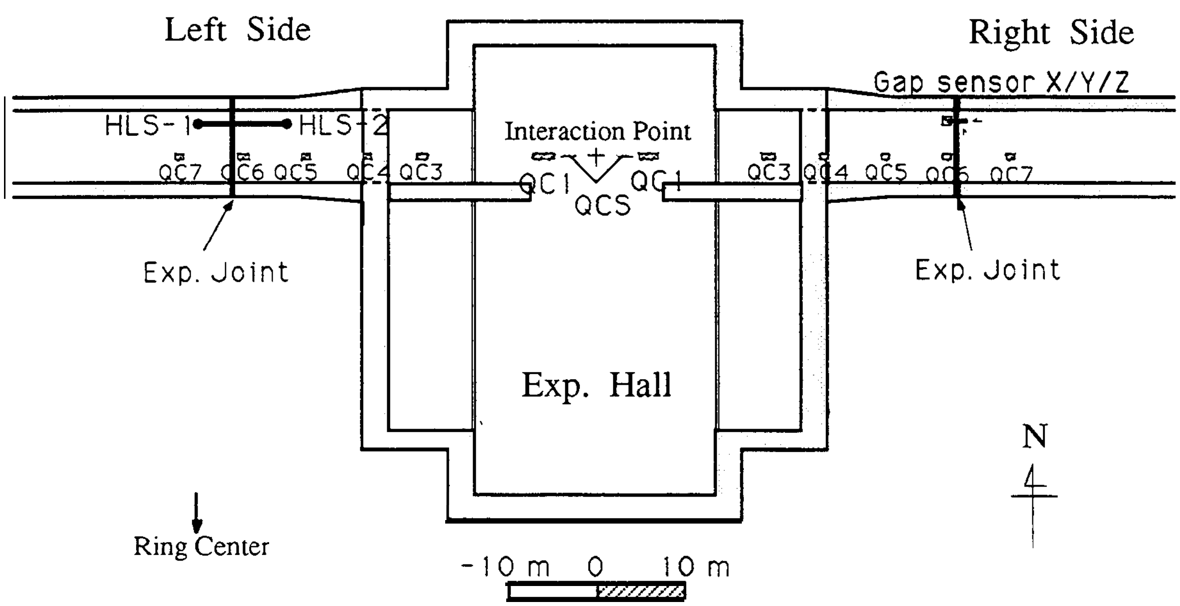

Fig. 1 Plan view for the TRISTAN experimental hall.

The movement of beams will be controlled by the steering field of magnets at the speed of about 10 Hz in the B-factory. Therefore the amplitude of the motion of magnets at the speed faster than 10 Hz has to be less than 0.1 μm in the interaction region. The slow motion has to be not so big as well: less than about 0.1 mm/day.

2. SEISMIC MOTION

Seismic motion was measured on the concrete floor, on movable bases for magnets and on QC1 magnets, the closest quadrupole magnets to the interaction point, in Fuji and Tsukuba experimental halls. It was measured on the floor in the straight section as well.

High frequency component was measured by a moving coil type seismometer, Model L-4 of Mark Product, which measures the velocity of seismic motion in the frequency range higher than 2 Hz. The biggest vibration was observed in Tsukuba interaction region. Results are shown in Fig. 2, where (a) and (b) show the vertical and the horizontal motion of the base for the QC1 magnet respectively, and (c) and (d) show those measured on the back of the QC1 magnet. The power spectrum has the peak at 50 Hz and its harmonic frequencies. High components are eliminated at the QC1 magnet due to its spring coupling to the base. This vibration is attributed to rotary vacuum pumps. The amplitude of the vibration on the back of the QC1 magnet is about 0.2 μm in both horizontal and vertical direction. As rotary vacuum pumps will be turned off during the beam run, this vibration is not the case in the B-factory. Except for this 50 Hz vibration, the amplitude of the seismic motion is much less than 0.1 μm in the frequency region higher than 2 Hz. The slow component was measured by MG3 seismometer of Guralp Systems, which measures the velocity and is sensitive over the frequency range of 3 mHz - 10 Hz. In Figs. 3, 4 and 5 are shown power spectra for the seismic motion measured on the floor in the straight section, on

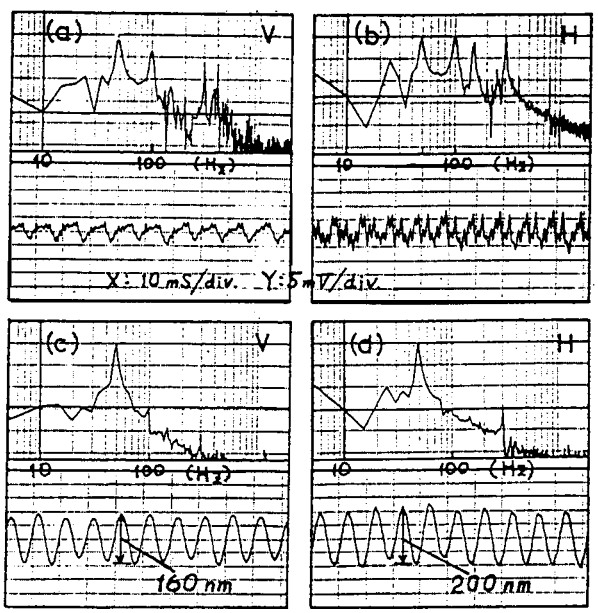

Fig. 2 Seismic motion measured (a,b) on the base for the QC1 magnet and (cd) on the back of the QC1 magnet. Figs (a,c) show the vertical motion, and (b,d) the horizontal motion respectively. In each figure the top graph shows the power spectrum and the bottom graph shows the output from measuring heads.

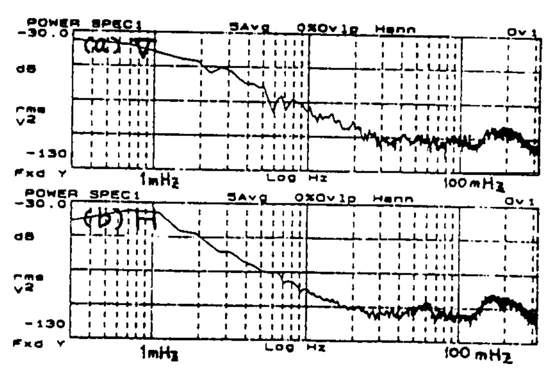

Fig. 3 Power spectra for (a) vertical and (b) horizontal seismic motions measured on the floor in the Tsukuba straight section.

the floor in the experimental hall and on the QC1 magnet base in Tsukuba region respectively. The top graph is the spectrum for the vertical motion and the bottom one for the horizontal movement. Although it is noisy on the QC1 magnet base, the amplitude of the motion is quite small: about 5 nm around 3 Hz, 1 µm around 0.1 Hz and 3 µm around 3 mHz.

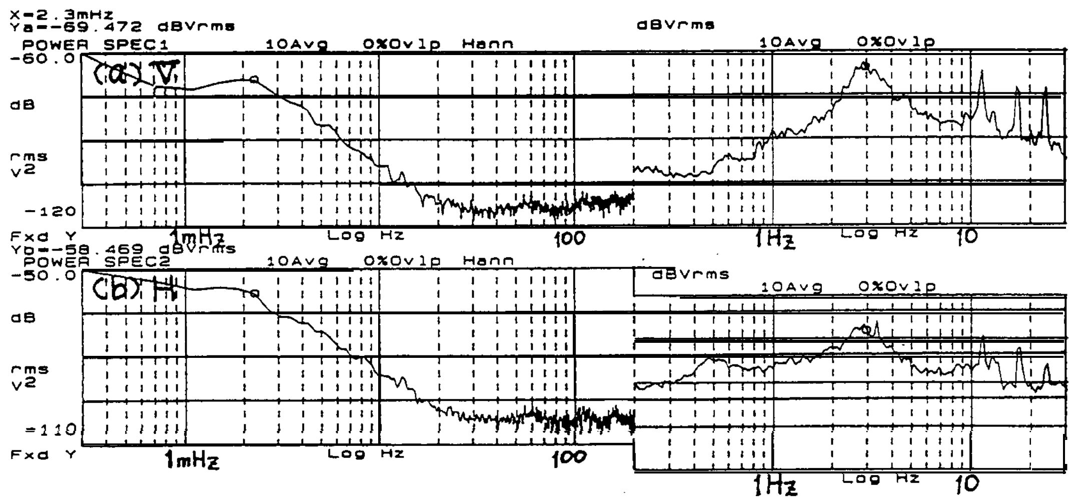

Fig. 4 Power spectra for (a) vertical and (b) horizontal seismic motion measured on the floor in Tsukuba experimental hall.

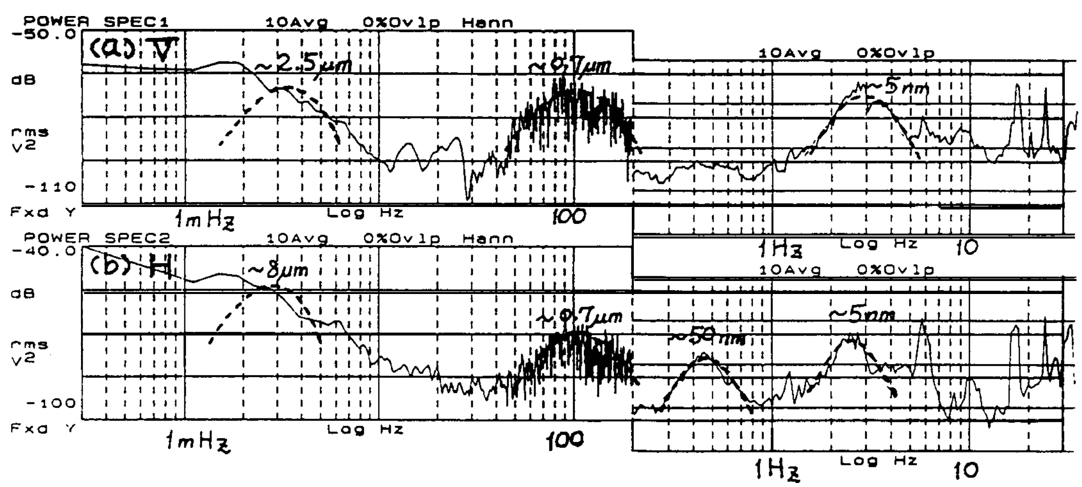

Fig. 5 Power spectra for (a) vertical and (b) horizontal seismic motion measured on the base for the QC1 magnet in Tsukuba experimental hall.

3. VERTICAL DISPLACEMENT OF THE FLOOR

Variation of the relative vertical displacement of the floor was measured in the straight section (see Fig. 1). Two measuring heads were placed about 10 m away from each other. Between those heads is located an expansion joint, where the tunnel is separated. The left and the right tunnels are connected softly to absorb the thermal expansion of the structure. This is the place where the left and the right tunnels can move independently. HLS (Hydrostatic

Leveling System of Fogal Nanotech)[2] was used to measure the relative vertical displacement. A schematic drawing for the setup is shown in Fig. 6. Two measuring heads

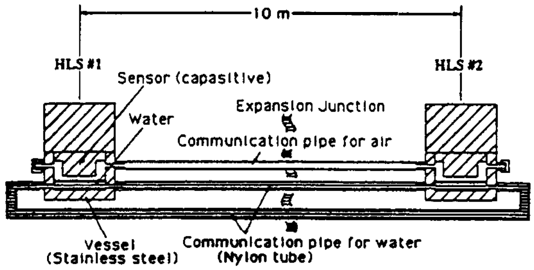

Fig. 6 Hydrostatic Leveling System.

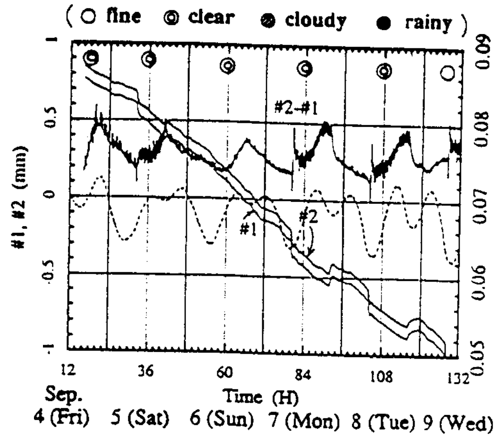

Fig. 7 Relative vertical displacement between two points, #1 and #2, 10 m away each other on the floor in Tsukuba straight section during the period Sep. 4-9, 1992. Weather marks are placed at the top, and the tide curve is shown by dotted line.

were connected by three communication nylon tubes of the inner diameter of 8 mm. Two tubes are for the water and the other one is for the air. At the stage of the preparation, water is circulated by a water pump to evacuate air bubbles from the water. The level of the water in the heads is measured by means of the capacitance measurement. The precision is 1 μm or better and the response time is about 40 seconds in our case. The response time is proportional to the pipe length and the inverse of the pipe cross section. Typical results are shown in Figs.7-9. Figs.7 and 8 show results for 5 days (Sep. 4-9) and 8 days (Sep. 28 - Oct. 7) respectively measured in Tsukuba straight section. Fig.9 is results in Fuji straight section for 5 days (Mar. 21-25). The water level drops gradually at the speed of about 0.2 mm/day, as the water evaporates from the surface of the

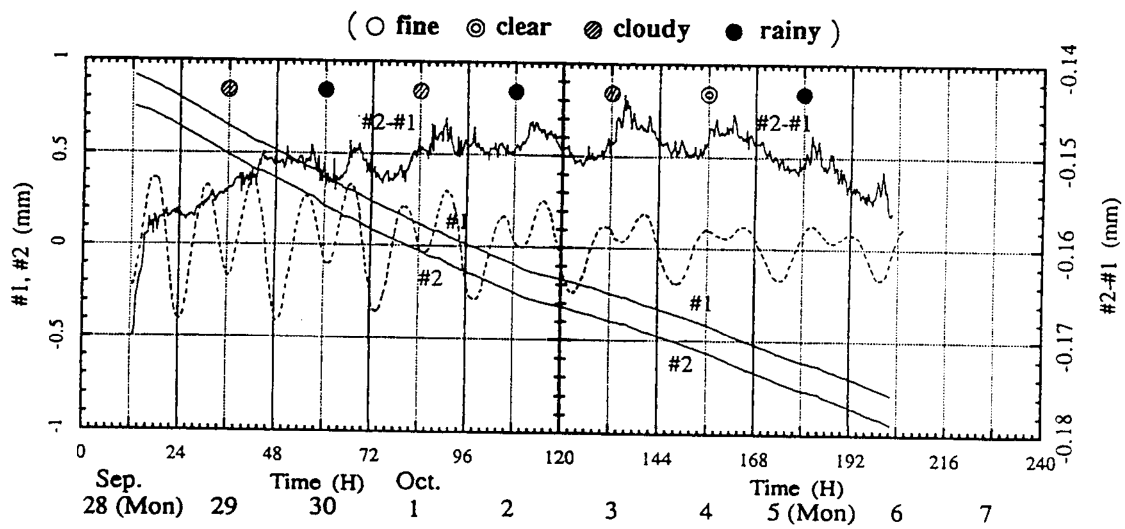

Fig. 8 Same as Figure 7, but during the period Sep. 28 - Oct. 7, 1992.

nylon pipe. During the period Sep. 4-9 (Fig.7) the air conditioner was turned on only at the day time on week days. As the evaporation of water is sensitive to the wind blowing, some jumps are seen in the output from each head at the time of turning on/off of the air conditioner. In Figs.7 and 8, the variation curve of relative displacement has peaks every evening, around 6:00 p.m. The amplitude of the variation curve is about 5 μm in peak-to-peak, and this structure is more evident during the period of Sep. 4-9 than the period of Sep. 28 - Oct. 7. The weather was very dry during the former period and it was rainy during the later period as can be seen by weather marks attached at the top of the figure. It is supposed that this variation of the relative displacement is caused by warm-up of the building and/or the ground by the sunshine. The tide curve, plotted in figures by dotted lines, does not explain this variation as mentioned in the reference [3]. During the period Sep.4 - Oct.7, no beams were circulated. On the other hand, beams were circulated for Mar. 11-15 (Fig.9). Besides the variation of one day period, in Fig.9 can be seen a fine structure due to the room temperature variation caused by the pattern operation of magnets: injection at 8 GeV taking about 30 minutes and flat top operation for about an hour. The room temperature changes by about one centi-grade by this pattern operation of magnets. Again the tide curve cannot explain the variation curve in Fuji straight section.

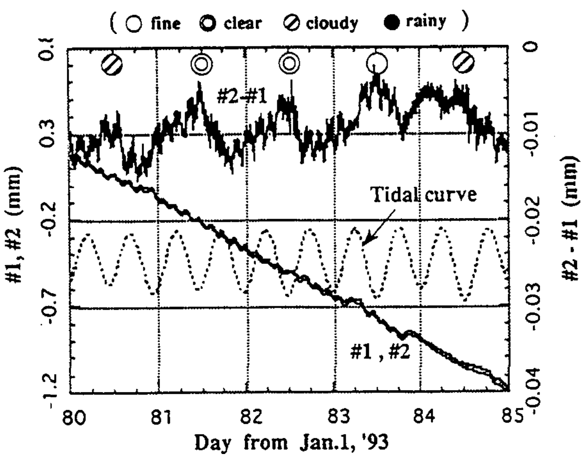

Fig.9 Relative vertical displacement between two points, #l and #2, 10 m away each other on the floor in Fuji straight section during the period Mar. 21-25, 1993. Weather marks are placed at the top, and the tide curve is shown by dotted line.

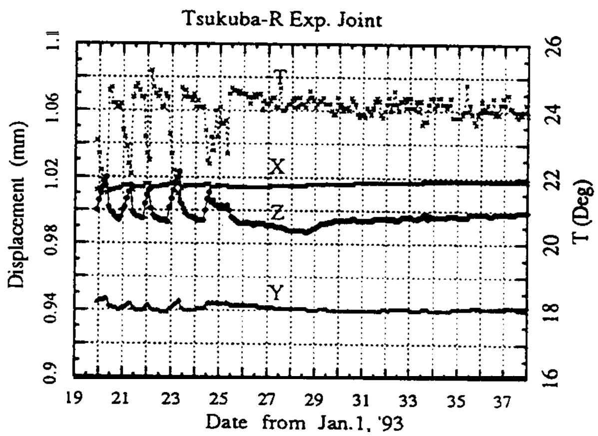

Fig.10 Relative displacement of the floor at the expansion joint in Tsukuba straight section.

4. RELATIVE MOVEMENT OF FLOORS AT THE JOINT OF THE TUNNEL

Relative displacement between the left and the right floors at an expansion joint in the straight section was measured using gap sensors. An iron slab was extended from one side and three gap sensors (X, Y and Z sensors), fixed on the other side, measure the gap between the slab and the sensor heads. The sensor is an Eddy current type. Fig.10 shows results obtained at Tsukuba expansion joint during the period of Jan.19 - Feb.7 (20 days). As it was a maintenance period till Jan.24 and the air conditioner was turned off at night, the room temperature changed much and the gap varied accordingly, especially in Z direction. Since Jan.25 the air conditioner had been tuned on all the day, and the room temperature and the gap became quite stable. Variation of the gap is less than 2 μm/day. On the other hand, temperature still changed much even the air conditioner was turned on all the day at Fuji expansion joint. Fig. 11 and 12 show the data taken in Fuji region for the period of Feb.8-12 and Feb. 16-26 respectively. Although temperature looks stable in Fig. 12, the gap varies much in 2 direction. It is supposed that beam injection lines are located in Fuji straight section and the temperature around the injection point was still unstable. It took about a month for the gap in 2 direction was stabilized. The gap in X and Y was quite stable even the room temperature varied.

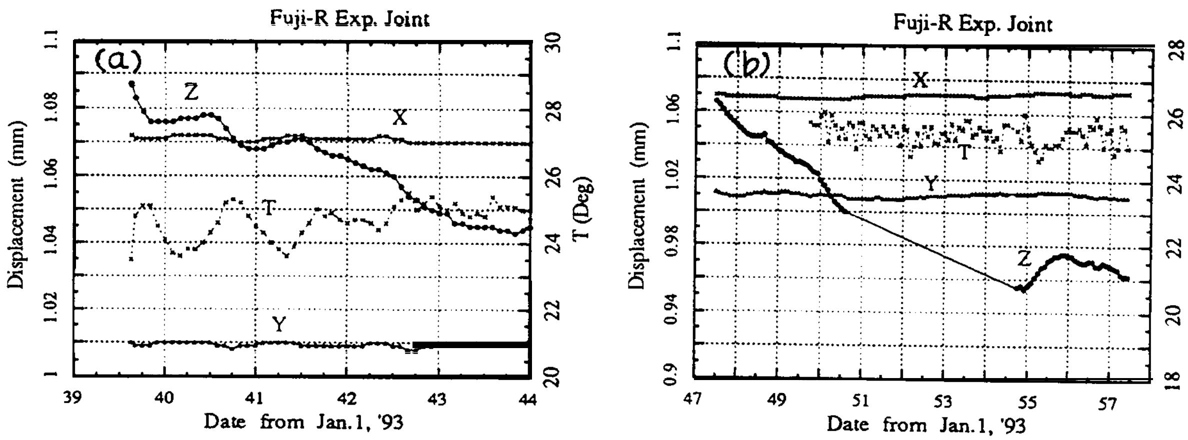

Fig.11 Relative displacement of the floor at the expansion joint in Fuji straight section during the period (a) Feb.8 - 12 and (b) Feb.16 - 26, 1993.

5. CONCLUSION

The seismic motion was measured on the concrete floor, on movable bases for magnets and on QC1 magnets, in Fuji and Tsukuba experimental halls. It was measured on the floor in the straight section as well. Amplitude of the seismic motion is the biggest on the QC1 magnet base in Tsukuba interaction region. Except for 50 Hz vibration caused by rotary vacuum pumps, amplitude is less than 10 nm in the frequency region higher than 1 Hz. In low frequency region, amplitude is about 1 μm around 0.1 Hz, and about 3 μm around 3 mHz.

In the straight section, variation of relative vertical displacement of the floor between two points 10m away from each other across the expansion joint of the tunnel was measured by using water communication tubes. The displacement varies with the period of one day. This variation seems to be caused by the warm-up of the building and/or the ground by sunshine.

The relative movement of separated floors at the expansion joint was measured by gap sensors. The movement in Z direction is sensitive to the variation of room temperature. The movement in X and Y direction is very small, less than 5 μm, even the air conditioner is turned off at night. The room temperature is controlled well in Tsukuba straight section, and the relative movement of separated floors is very small, less than 2 μm/day. On the other hand, it takes about a month for the relative movement in Z direction is stabilized in Fuji straight section. It is supposed that this happens because the cooling power of the air conditioner is not enough in Fuji section where injection lines are located.

ACKNOWLEDGMENTS

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REFERENCES

[1] S. Kurokawa *et al.*, Accelerator design of the KEK B-factory, KEK Report 90-24, March 1991.

[2] D. Martin and D. Roux, Internal Report of European Synchrotron Radiation Facility, Grenoble; Contributed to the Second Int. Workshop on Accelerator Alignment, Hamburg, Sep. 10-12, 1990.

[3] S. Takeda *et al.*, KEK-Preprint-92-67, Jul. 1992; Contributed to the 15th Int. Conf. on High Energy Accelerators, Hamburg, Jul. 20-24, 1992.