Long Term Positional Stability of TRISTAN-MR Magnets

Y. Ohsawa, H. Fukuma, M. Uchiyama* and K. Endo
National Laboratory for High Energy Physics
1-1 Oho, Tsukuba-shi, Ibaraki-ken 305, Japan
and
*Leica K. K.
2-17-22 Akasaka, Minato-ku, Tokyo 107, Japan

ABSTRACT

One of the problems in TRISTAN-MR is the frequent change of the vertical closed orbit distortion (COD). As COD during operation is mainly caused by the transverse movements of the quadrupole magnets, their movements were measured with precise tilt meters especially on the strong focusing magnets at an experimental hall. Observations shows the un-coincident movements between quadrupoles to an order of 10 μm which cannot be discard for the machine operation.

INTRODUCTION

Duo to the change of COD the beam current and luminosity decrease significantly and therefore the frequent COD correction has been required to maintain MR in good condition. It is one of problems in the operation of TRISTAN-MR[1]. The closed orbit error is caused mainly by the transverse displacements of the quadrupole magnets, but their displacements are so small that the very sensitive transducer must be used.

Recently the precise tilt meter NIVEL20 (inclination sensor) of Kern having the resolution of 1 μrad can be available on the market with a personal computer for data acquisition. Time interval between measurements can be set arbitrarily at least 1 sec. Several tilt meters were set on the quadrupole magnets at Tsukuba experimental hall for a month before the summer shutdown of 1991 and two directional tilts, longitudinal and transverse, were measured simultaneously at 1 hr intervals. At the same time the temperature was recorded at each point of the tilt meter.

MEASURING SYSTEM OF TILT METERS

Each quadrupole magnet has a machined surface on its top for the precise alignment. Level of the magnet was adjusted measuring the tilt of this surface with the coincidence level of Carl Zeiss Jena [2,3]. The tilt meter is conveniently fitted to this surface and mounted without any care.

As shown in Fig.1, 4 tilt meters were connected through the RS-485 cable via Lemo-Lemo connectors which enable the long distance measurements. Close to the computer terminal RS-485 is converted to RS-232 standard with a bus converter.

The tilt meter operates according to an opto-electronic principle. The horizontal plane is given by a free fluid surface enclosed in a sealed container and inclination is given by an angle between the fluid surface and the base of the container. This angle is measured by a combination of a light emitting diode and a photo detector [4]. As the sensor is unaffected by magnetic field, it can be mounted on the magnet with no shielding material.

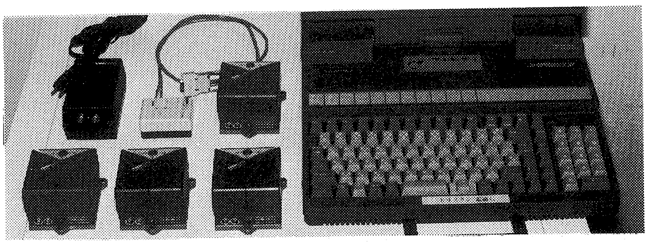

Fig.1 System of tilt meters.

The sensor receives an influence of the temperature and needs the calibration against the ambient temperature change. Calibration was undertaken in the separate rooms both on the ground level and underground as below as 15 m from the ground surface. In the room on the ground level, however, it was difficult to separate the inclination of the building from calibration data. Fig.2 gives the law calibration data taken for 2 days. It shows the gradual inclination of the building in the morning and the gradual reverse inclination in the night. The effect of the building itself amounts to 100 μrad or more. While in the latter room underground, inclination of the building was decreased to an unobservable level, but the thermal expansion or contraction of the support, such as the concrete and the granite pedestal on which the sensor is mounted, gives a disturbance. The behavior of this type is given in Fig.3 in which the square variation of the inclination show the repeated change of the room temperature due to the forced on and off of an air conditioner at an interval of 12 hrs. Fig.4 gives the harmonic components of these data showing the correlations between temperature and tilt.

Sudden changes of tilts can be accounted by the thermal expansion and contraction of the supporting structure of which deformation is estimated to be a few μm/C which causes tilt of the stage more than 10 μrad. If a sudden change of the ambient temperature is rejected, the temperature coefficient of the sensor obtained during the gradual change of both room and sensor temperature is less than ±2.5 μrad/C in both x and y direction of the sensor. This value is so small to discuss the magnet movement, because the movement in the radial direction deduced from tilt data is less than 10 μm. Whereas, the magnet height is less than 0.1 μm from the tilt and is more than 1 μm from the thermal expansion or contraction. In the following, no correction was made of the tilt data.

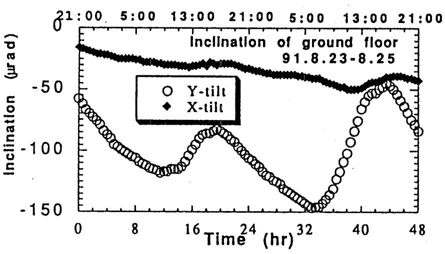

Fig.2 Inclination of the ground floor due to the variation of outdoor temperature, while the room temperature was maintained constant.

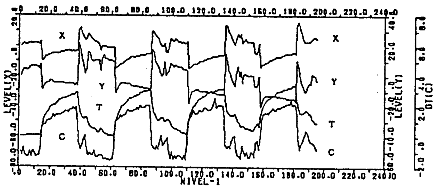

Fig.3 Tilt meter response to sudden room temperature variation. Top two traces give tilts in x and y direction (X & Y). Bottom two are temperatures of NIVEL20 (T) and Cu-Constantan (C) thermocouple (lowermost).

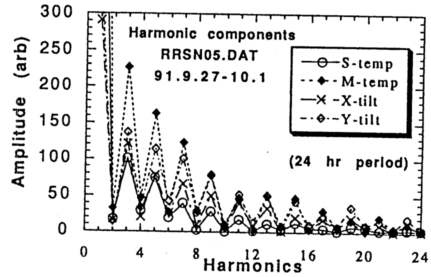

Fig.4 Harmonic components in responses of Fig.3.

MAGNET INCLINATION MEASUREMENT

During June of 1991, the movement of quadrupole magnets at Tsukuba experimental hall were measured with 4 NIVEL20 tilt sensors. The tilt data in both longitudinal and transverse directions and temperature of each sensor were stored in the hard disk at an interval of 1 hr for successive 18 days. Variations of tilt and temperature are given in Fig.5. Two top traces are tilts in x (longitudinal ; uppermost) and y (transverse) direction. Lower two traces are temperature variations of room sensor for the temperature control (lowermost) and NIVEL20. 4 sensors were mounted on both ends of quadrupoles, QC1-L and QC1-R. QC1-L and QCS-L are mounted on the same movable girder, and QC1-R and QCS-R are on another movable girder. Both sensors close to the colliding point sense the temperature of individual QCS (superconducting quadrupole) magnet. Average temperature of two sensors on the same QC1 magnet is assumed as the ambient temperature of respective quadrupole magnet. Fig.5(a) and (b) are data taken at extreme ends (far ends of QC1-L and QC1-R from collision point).

To see the coincident behaviors of quadrupole magnets with the temperature variation, harmonic components of tilt and temperature are obtained as in Fig.6(a), (b) and (c), respectively. There is a small peak at the 6-th harmonic (corresponding to 4 hr period) in both tilt and temperature. The solid circle shown in Fig.6(c) is the temperature harmonic components obtained from the Pt thermo-sensor for room temperature control, giving small peaks at the 5-th and 10-th components.

Assuming the 3 m height of the quadrupole median plane from the base of its girder made of iron, the radial and vertical displacements of QCS-L and QC1-R were obtained from tilt and temperature data as given in Fig.7(a) and (b), respectively.

ESTIMATION OF COD

The radial displacement is less than ±10 μm. It is very small compared to the height variation as shown in Fig.7. If only the height difference of Table1, which was extracted from data when beam was existing in the TRISTAN-MR, is considered, the vertical COD is estimated using PETROK code as in Fig.8. Assuming zero COD at 6:00, two cases were calculated for examples at interval of 6 hrs. Results show that the height variation of high gradient quadrupole such as QC1 and QCS will give large contribution to COD even if it is as small as 20 μm.

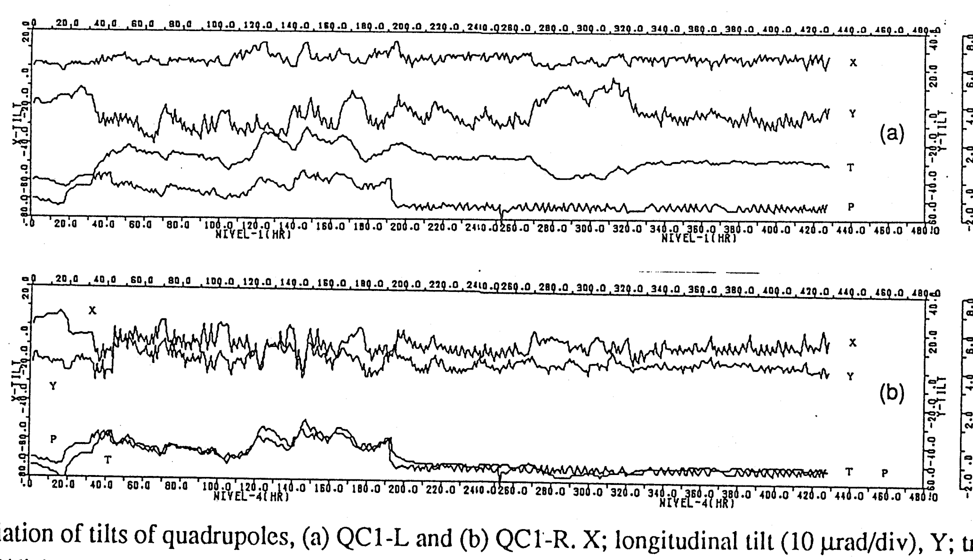

Fig.5 Variation of tilts of quadrupoles, (a) QC1-L and (b) QC1-R. X; longitudinal tilt (10 μrad/div), Y; transverse tilt (10 μrad/div), T; NIVEL20 temperature and P; Pt thermo-sensor (1 C/div).

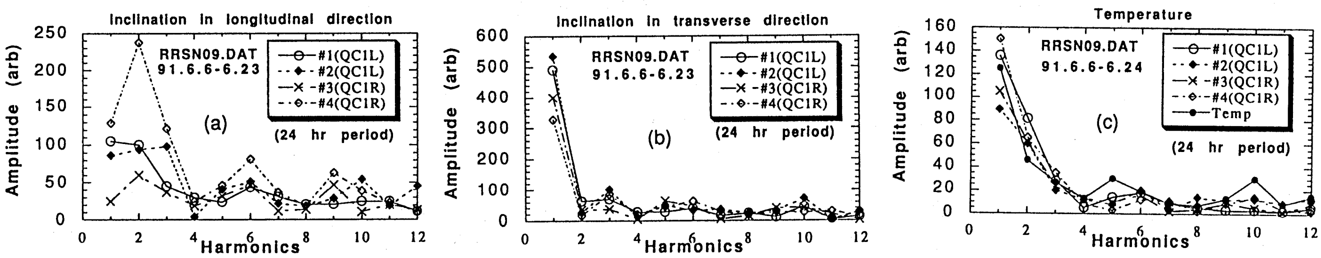

Fig.6 Harmonic components of tilt and temperature of quadrupoles of all data taken from June 6 through 23, 1991. (a) longitudinal tilt, (b) transverse tilt and (c) temperature.

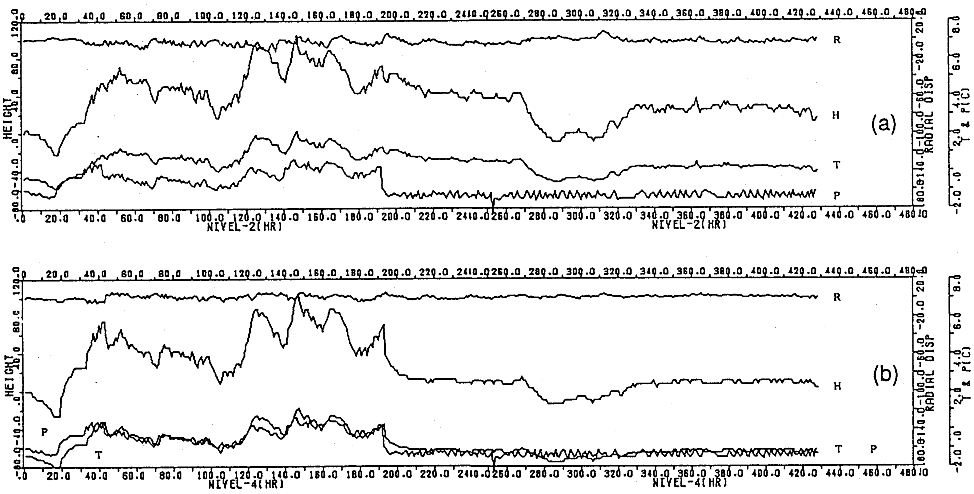

Fig.7 Horizontal displacement and vertical height variation of (a) QCS-L and (b) QC1-R. Temperature data are same as in Fig.5 and the NIVEL20 temperature is relative to that of Fig.5(a). R; radial displacement (20 μm/div), H; height variation (20 μm/div), T; NIVEL20 temperature and P; Pt thermo-sensor (1 C/div).

Table1

Height variation of quadrupoles at Tsukuba experimental hall (unit:μm, 91.6.8)

Time	QC1-L	QCS-L	QCS-R	QC1-R
6:00	0.0	0.0	0.0	0.0
12:00	4.2	4.3	4.2	-8.4
18:00	21.0	21.1	21.0	8.4
24:00	8.4	8.5	8.4	-6.3

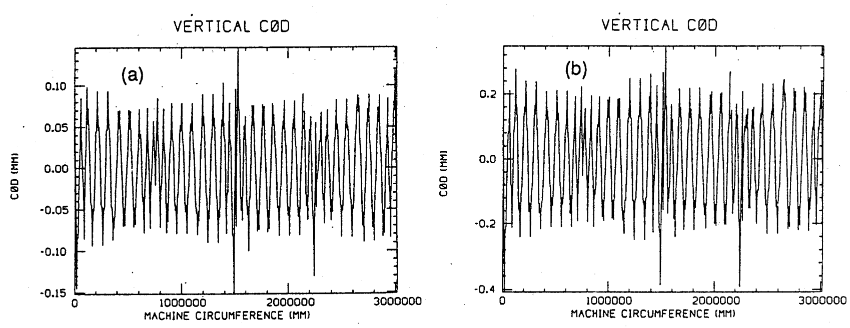

Fig.8 Estimated COD changes after 6:00. (a) 12:00 and (b) 18:00.

Measurements were tried at one colliding region (Tsukuba). It is expected that Fuji region gives the similar contribution to COD because both regions have the same structural configurations. But another colliding regions (Nikko and Oho) are expected to give less effect if the temperature variation is comparable because the supporting structure height of quadrupoles is half of that of Tsukuba and Fuji.

There is a spatial temperature distribution in an experimental hall. From the measurement of the magnet movements, every magnet behaves randomly according to the ambient temperature. It is concluded that COD gradually increases to an un-tolerable magnitude if COD correction is not done occasionally and it takes infinitely long time to restore the original COD without correction.

REFERENCES

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