

CORRECTION OF CLOSED ORBIT DISTORTION IN TRISTAN ACCUMULATION RING

H. Fukuma, S. Kamada, E. Kikutani, K. Nakajima and M. Tejima
National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305, Japan

Summary

The closed orbit distortion in the TRISTAN Accumulation Ring has been corrected to 0.6 mm of the horizontal rms value and 0.3 mm of the vertical rms value. The method of the correction is based on the least squares theory. The correction is easily performed from the touch panel in the central control room.

Introduction

The TRISTAN Accumulation Ring(AR), which has been operated since November 1983 with electron beam, is a storage accelerator which accumulates 2.5 GeV electrons and positrons from the Linac and accelerates them up to 8 GeV to inject into the Main Ring. AR also can be used as an electron-positron collider, a synchrotron light source and a gamma ray source. The gamma ray is produced by irradiating the internal targets by the electron beam and the converted electrons are being used to calibrate the lead glass Cherenkov counters¹).

The closed orbit distortion (C.O.D.) is mainly induced by the alignment errors and the field errors in magnets. In AR, the C.O.D. induced by the 56 main dipoles and the 86 main quadrupoles was estimated at about 13 mm of horizontal maximum value and about 4 mm of vertical maximum value. As this distortion decreases the available machine aperture, we must correct it by the dipoles called corrector.

In following sections, the closed orbit correction system and the results of the correction are described.

Closed orbit correction system

The schematic diagram of the closed orbit correction system is shown in Fig. 1.

Hardware system

The corrector consists of 44 vertical steering dipoles(STV), 10 horizontal steering dipoles(STH) and 56 back-leg windings(BW) on the yoke of the main dipoles. STV's are located

near every defocusing quadrupoles for exerting an efficient correction. STH's are placed near interaction points and rf sectors where the dipoles are not located.

The C.O.D. to be corrected by these correctors is measured by 83 "button" type monitors located close to almost all quadrupoles.

The control of the correctors and the readout of the C.O.D. are performed by process control computer HIDIC-80E's.

Software system

The software system, which works under the KEK NODAL system²), mainly consists of five parts--(1) measurement of the C.O.D., (2) computation of the C.O.D. correction, (3) control of the correctors, (4) arithmetic operation of the C.O.D. data and (5) file management. The whole system is controlled from the touch panel connected to operation computers(OP0, OP1 and OP2) in the central control room.

Measurement of the C.O.D.

The C.O.D. is measured by the beam monitor computer(BM0) and the data are temporally stored in the library one(LB0). The measured C.O.D. can be displayed on a graphic display and be printed out on a serial printer.

Computation of the C.O.D. correction

The C.O.D. correction is computed with the computer code PETROK, which is a KEK version of the optics code PETROS originally developed at DESY. In the form of its subroutine, PETROK is furnished with the least square minimization code MICADO and manages the C.O.D. correction in the following way³).

- Step 1. Find the most effective corrector among the available ones and calculate the strength of it, where the strength means the deflection angle by the corrector.
- Step 2. Find the most effective corrector among the remaining ones when used with the first one and calculate the strengths of them.

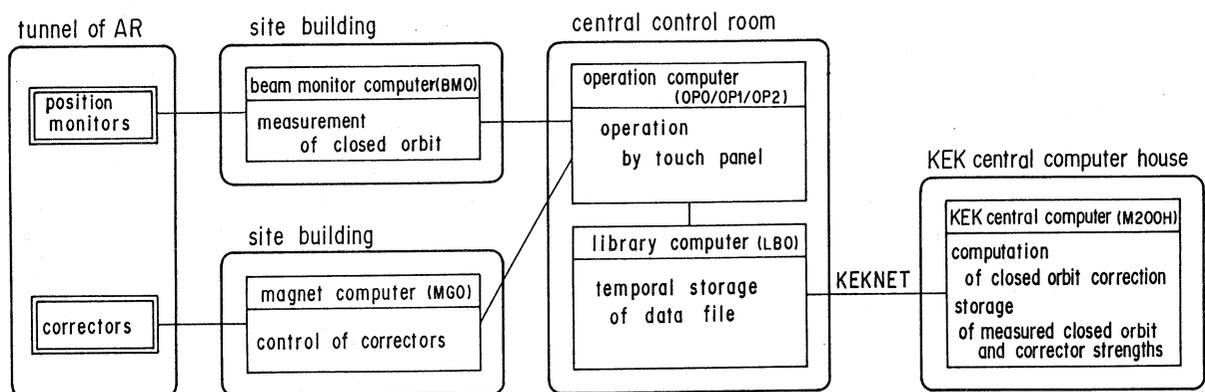


Fig. 1 Schematic diagram of the closed orbit correction system.

Step 3. Find the third corrector in the same way and calculate the strengths of these three correctors.

Step 4. and so on.

PETROK repeats the step until the number of the selected correctors reaches the previously specified one.

PETROK and some unaltered data such as the positions of the correctors and the monitors reside in the KEK central computer(M200H) and are controlled by the KEK NODAL system via KEK-NET 4).

The measured C.O.D., measured betatron tunes, tracking ratios of the quadrupoles and the sextupoles, present corrector strengths and some correcting conditions make up the input data for PETROK. The measured tune is necessary only when the optics calculated by PETROK is far from real one. Unavailable correctors and position data of doubtful monitors can be omitted from the correction by setting the flag.

The output data of PETROK consists of corrector strengths and an expected residual C.O.D. after this correction. Viewing the residual C.O.D. and the corrector strengths on the graphic displays, operators can judge whether this correction is good enough to be installed in AR or not.

For further investigations and corrections of the C.O.D., PETROK is furnished with the following functions which work on the demand of the correcting conditions.

1. Reset-mode is prepared to decrease the total number of working correctors. In the usual mode new correction is added to previous one, then the total number increases after each correction.
2. The rf frequency shift which causes momentum error, is calculated on demand.
3. An expected C.O.D. is simulated for the corrector strengths given arbitrarily.

Control of the correctors

The correctors are excited by the magnet computer(MGD) by using the corrector strengths transferred from LBO.

Arithmetic operation of the C.O.D. data

The C.O.D. data, which may be measured or calculated one, can be subtracted from or added to another one. The data can be also multiplied by a constant factor.

Among the three operations, the subtraction is especially useful, for the unexpected movement of the C.O.D. can be found by inspecting the difference between two C.O.D.'s measured at different time. Moreover the dispersion function can be easily measured by making the difference between the two orbits which are measured at two different settings of rf frequency.

File management

The data of closed orbit and corrector strengths are filed in M200H. Some functions such as reading directories, deleting a file and condensing a file can be used.

Operational experiences of the system

First closed orbit correction was successfully performed after a month later from the start of the commissioning of AR. Some improvements of the software system based on experience through six months were made at April 1984.

C.O.D. correction and error sources

Correction of measured C.O.D.

At present AR is mainly operated by using the optics named "IT01", which is the set of the strengths of the quadrupoles and the sextupoles for the internal target operation 5). The strengths of the sextupoles are raised by 20 per cent from the calculated ones which give zero chromaticity. The calculated horizontal and vertical tunes are 10.15 and 10.20, respectively.

In this optics the uncorrected orbit at the injection energy of 2.55 GeV is shown in Fig. 2 as the black dots. As the calibration of the position monitors was performed in the range of ± 10 mm horizontally and ± 6 mm vertically, the horizontal beam positions whose absolute values exceed 10 mm may have some systematic errors.

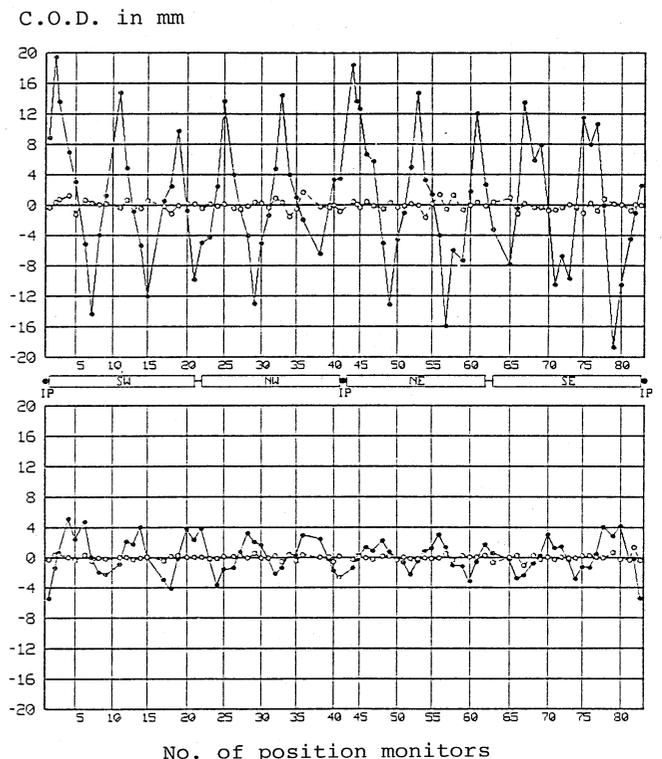


Fig. 2 C.O.D.'s before and after correction. IP means a interaction point.

This C.O.D. was corrected by the iterative way described as follows.

- Step 0. Set the strengths of all correctors to 0.
- Step 1. Measure C.O.D. .
- Step 2. Calculate the correction of C.O.D. using M correctors by MICADO .
- Step 3. Add the calculated corrector strengths to present ones.
- Step 4. Set the corrector strengths to the correctors.
- Step 5. Change M into N and goto step 1.

Fig. 3 shows the rms deviations of the C.O.D. for six successive iterations, where M and N were selected to 15 and 10, respectively. The first iteration for horizontal correction was

performed by omitting the C.O.D. data more than 10 mm of the absolute value. It can be seen that four iterations are sufficient and the C.O.D. has little improvement for further corrections.

rms value in mm

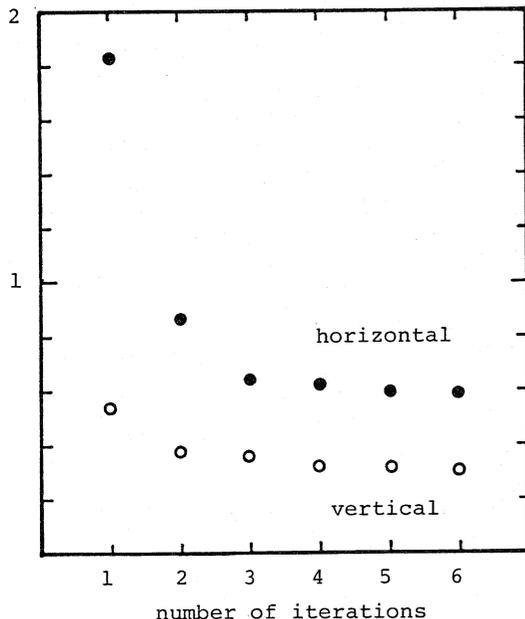


Fig. 3 Measured orbit deviations for successive iterations.

The open circles in Fig. 2 show the corrected C.O.D. after four iterations. The horizontal rms deviation is reduced to 0.6 mm and vertical one to 0.3 mm. The number of required correctors were 33 horizontally and 31 vertically.

Estimation of error sources

The open circles in Fig. 4 show the C.O.D. which is estimated from the measured values of the field errors in the main dipoles, alignment errors of the quadrupoles and the remanent fields in the bump magnets. The effect of the sextupoles is taken into account in this estimation. The misalignment of the quadrupoles was measured in the autumn of 1983⁶⁾.

The C.O.D. measured at July 1984 is shown in Fig. 4 as the black dots. The calculated rms deviation is 7.0 mm horizontally and 1.8 mm vertically. The agreement of the estimated and measured data is fairly good, though the civil engineering work for the Main Ring is been undertaken near AR.

Correction of estimated C.O.D.

The correction of estimated C.O.D. can be computed iteratively by MICADO as described before. The results after four iterations for $M=10$ and $N=10$ give 0.2 mm rms value of the horizontal C.O.D. and 0.1 mm of vertical C.O.D., while the measured C.O.D. was not corrected better than 0.6 mm rms value of horizontal C.O.D. and 0.3 mm of vertical C.O.D..

The estimation which takes into account of the reading errors of the correctors and the setting errors of the correctors is under way.

Miscellaneous

In the course of the operation, the unexpected movement of the vertical C.O.D. was observed. The simulation by PETROK showed that it

was explained if the insertion quadrupoles, which are mounted on the bridge made from iron, moved vertically by 150 microns. Actually, it was confirmed by the measurement of the quadrupole's level that the quadrupole moved by the consistent value, as the temperature of the bridge girder varied.

Besides the above trouble, there still remains the unexplained movement of the C.O.D..

C.O.D. in mm

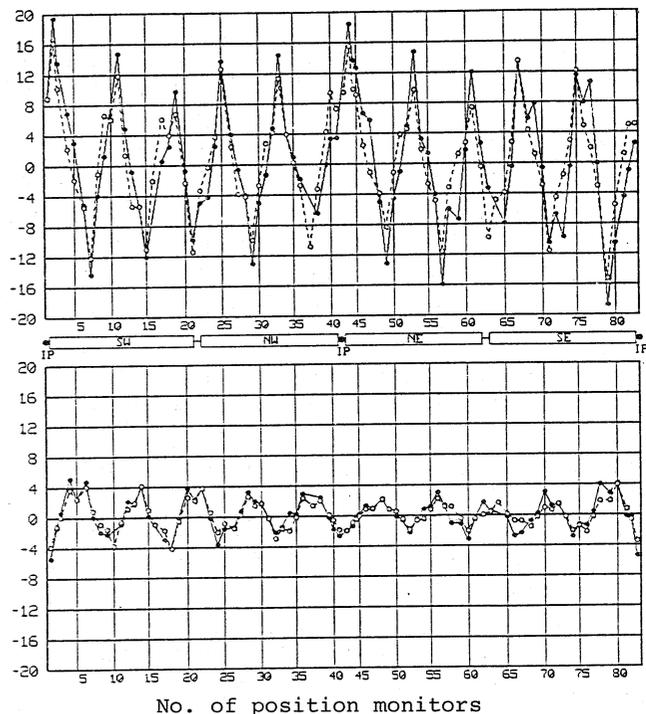


Fig. 4 Measured and estimated C.O.D. before correction.

Acknowledgement

The authors wish to thank the members of TRISTAN operation group and the TRISTAN control group for their useful discussions.

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